THE HAWAIIAN PLANTERS' RECORD

Volume XXXI. OCTOBER, 1927 Number 4

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Forestry on Oahu*

By H. L. Lyon

The first and most difficult step in carrying out adequate forestry work on Oahu has been accomplished. This was the securing for forest reserves of the watershed areas on Oahu which should be covered with forests. The adequate protection of these areas from invasion by cattle is assured and will be an accomplished fact within the next few months. After the cattle are removed from the reserves we shall still have one serious animal pest to contend with. Wild pigs are extremely numerous in the Koolau Mountains. They stay well back in the valleys and in fact seem to be most numerous and most destructive at the very heads of the valleys. They are clearing out the undergrowth and preparing the soil to receive Hilo grass and staghorn fern. It is imperative that we make strenuous efforts to eliminate the pigs from our forests. It is generally held that the only effective method to accomplish this result will be to hunt them down with dogs. This will require the persistent efforts of numerous hunters, and to make their work effective they must be paid wages in addition to the meat which they are able to bring out. Men hunting pigs only for sport or for meat will never complete a campaign of extermination. The issuing of hunting permits to all those requesting them will not go very far towards accomplishing the desired result, and a very serious objection to free-for-all pig hunting within the reserves is the danger that irresponsible hunters will start forest fires. We believe that a well conducted campaign of poisoning would be the most successful method of handling the pig problem. There are several effective poisons which could be used safely in such a campaign; their distribution on the watersheds in no way jeopardizing the lives of the people and stock drinking the drainage water therefrom.

---

* Communicated to the Forestry Committee, A. F. Judd, chairman, devising a forestry program for Oahu.

There can be no doubt that the remnant of native forest on the watersheds of Oahu is doomed to pass out of existence in the next hundred years if our only efforts are such as are designed to protect it. The old trees are dying one by one and there are very few young native trees coming on to take their places. Hilo grass and uluhi quickly take over and hold each new opening made by the fall of a veteran tree, and if nothing intervenes our watersheds will eventually be covered with these and other pernicious weeds to the exclusion of all tree growth.

A third introduced plant which now threatens to become as troublesome in the forests on Oahu as is either Hilo grass or uluhi is the so-called Para grass, *Panicum barbinode*. The extensive use of this plant on the pineapple plantations for fodder and green soiling purposes is responsible for its wide distribution along the border of our forests and it has already penetrated to considerable depths at many points. With its long runners it climbs over young trees and smothers them down quite as effectually as does the uluhi, and the thick mat of coarse, tangled stems with which it covers the soil prevents the growth of seedling trees.

Firebreaks

The staghorn fern or uluhi now extends from the margin of the forest to the very summit of the Koolau Mountains, and constitutes, during dry weather, a continuous blanket of inflammable material covering the most important watershed on Oahu. Should a fire get well started in this uluhi, it is certain to spread over a very large area before we can get it under control and it is quite possible that it would sweep the entire length of the Koolau Range. It is imperative, therefore, that we take steps to divide this blanket up into sections by trails along which we can meet and stop any fire that may get started. These trails should properly run along some of the ridges extending from the edge of the forest to the summit of the backbone ridge. We should endeavor to make these trails permanent firebreaks by creating along them a mesophytic, fireproof forest which will forever hold back the uluhi.

Reforestation

The reforestation of our watersheds requires operations of two distinct categories. First, the reforestation of denuded lands, and second the rejuvenation of existing forests.

It has been often stated that the proper method of procedure to bring about the reforestation of our denuded lands would be to plant small groves of trees at intervals and then wait for the intervening spaces to be planted up by the natural spread of the trees previously planted. Such a process would require a very long period for the successful accomplishment of the desired result. A large part of the denuded areas is covered with Hilo grass, uluhi, lantana and guava, and these hardy plants are going to vigorously contest the progress of any trees which we may pit against them. The reforestation of these denuded areas is of such great economic importance to us that I believe it should be accomplished by

the speediest and surest methods available, and these are the actual planting out of trees at regular intervals over all the denuded lands.

We are most vitally interested in the watersheds included in the Ewa, Kawailoa, Kahuku, Kaipapau, Mokuleia and Honouliuli forest reserves. A careful survey by Mr. McEldowney shows that there are approximately 15,000 acres of denuded land within these reserves which should be reforested. Planting on the average 100 trees to the acre, 1,500,000 trees will be required to cover this area. A logical program would call for the planting of these trees in 10 years or at the rate of 150,000 trees a year. It would hardly be advisable to exceed this quota, at least, not during the first 5 years or until we are better able to judge of the success we are attaining in building up an effective water-conserving forest formation. As a general rule, we think these trees should not be planted closer than 20 feet apart each way. Trees so planted will eventually shade out the grass and uluhi and create conditions suitable for the germination of the seeds which they will produce. The general practice which we would advocate is the cutting of trails through the grass and scrub and the planting of trees at intervals along these trails. On areas covered by uluhi it is sometimes possible to isolate large blocks of the fern with firebreaks and then burn off these isolated blocks. The uluhi closes in very slowly on trails which have been cut through it and trees planted along such trails need attention two or three times only before they are above the fern.

Given trees of a suitable size for planting we can clear out trails, dig holes and plant these trees on denuded lands at an average cost of 10 cents per tree. We have averaged as low as 6 cents on some areas, but clearing of lantana and uluhi and difficulties of transportation have run the costs up rapidly on other areas. Our figures on the cost of caring for trees after planting and until they are able to shift for themselves are less satisfactory, but we are sure that this work can be accomplished at a cost not exceeding 3 cents per tree.

Rejuvenation of Existing Forests

As previously stated, it is obvious that the native trees on Oahu are rapidly passing out of existence and that they are showing no signs of recovering our watersheds through the establishment and growth of young seedlings of their own species. Hilo grass and uluhi have spread throughout the forests, covering the forest floor and effectually checking the reproduction of the native plants. What we really need to do under the circumstances is to introduce into our waning forests some tree or trees that will rapidly replace the declining native trees. Unfortunately we have at hand no tree, either native or introduced, the seedlings of which can develop unaided on soil covered with Hilo grass or uluhi. It is impracticable to attempt to cut trails throughout our existing forests and set out trees along these trails. What we must have are trees that will spread through the forests in their present condition and give us a covering equal to or superior to the native forests. Several species of figs already introduced promise to fulfill these requirements, for their seeds, carried about by birds, germinate on the branches

of other trees or on stumps and fallen logs and from such elevated positions the seedlings send down their roots to the soil and eventually establish themselves as independent trees. Because of the perching habit of their seedlings these trees can spread through our declining forests despite the prevalence of Hilo grass and uluhi on the forest floor. We should therefore continue to plant figs in small groups at intervals on our watersheds and in the course of time the resulting trees will supply the seed to bring about natural rejuvenation of our declining rain forests. We now have two species of figs on this island which are producing viable seed. These are both good trees but the evidence obtained in our various arboretums indicates that other species would prove more efficacious under our conditions. Among the most promising species are: *Ficus retusa, F. nota, F. glomerata, F. altissima, F. elastica,* and *F. bengalensis.* We believe that efforts should be made as soon as possible to introduce the wasps associated with each of these species in order that our local trees may produce viable seed and at once become factors in the rejuvenation of our rain forests.

The Uluhi Problem

A few years ago the writer called attention to the serious obstacle which the uluhi presented to any program of reforestation. He has also pointed out the serious fire menace which it creates in our forests. He is probably responsible, therefore, for the impression that has gained credence in some quarters that we can not have new forests as long as we have uluhi. This is far from the truth. At present the uluhi is probably the most serious obstacle to cheap reforestation on Oahu, but if we did not have uluhi we might easily have something else quite as bad or even worse, and if we could remove the uluhi completely at this time it is quite possible that Para grass would offer even a more serious problem at the end of another 5 or 10 years. The only way to successfully control a pestiferous plant of this sort is to pit against it some desirable plant or plants that can successfully fight it and take the ground away from it. The difficulty at the present time is that we are not pitting against the uluhi plants that can cope with the particular tactics which it employs.

Uluhi can be successfully suppressed by shading out with plants of greater stature. A dense forest formation could move slowly into territory occupied by uluhi by shading the fern out along the margin of the forest and thus making the ground suitable for young trees and shrubs that naturally spring up in the shade. Uluhi can be successfully pushed back by plants which will send runners underneath it from which shoots will grow up through its blanket and overtop it in the manner characteristic of certain bamboos. We have already successfully introduced several plants which produce root suckers. These root suckers spring up at intervals progressing outward from the parent plant in all directions and invading the surrounding country like a marching army. Another type of plant which is successfully combating the spread of uluhi is one which climbs over its blanket producing a mass of vegetation above it and thus smothering it down. The common aroid, *Pothos aureus,* is proving very effective in a contest of this

sort. It is a vigorous growing, fleshy vine producing very large leaves. It can grow in full sunlight, but it prefers partial shade. It burrows through the blanket of uluhi and overtops it with a mass of heavy, dense foliage. It seems to delight in the conditions which the uluhi affords. *Pothos aureus* has never been known to produce flowers and seeds but it is easily propagated from cuttings and it will be a simple matter to distribute these in an uluhi-infested area.

The success attained with *Pothos aureus* has encouraged us to seek other vines that might prove equally efficacious in combating uluhi. Vines are an essential element in a tropical rain forest and any vine that we may introduce for combating the uluhi will remain as a desirable element in the forest formations which we hope to build.

To recapitulate, I would say that the most serious obstacles to forestry work on Oahu have already been overcome. We can now formulate and execute a program for the conservation of existing forests and the creation of new forests. This program should provide for:

1. Elimination of pigs.
2. Creation of firebreak trails.
3. Planting up of denuded lands.
4. Rejuvenation of existing forests by introduction of figs and other plants that can spread through these forests in spite of the Hilo grass and uluhi which now control the forest floor.

The Application of the Principles of Base Replacement to Reservoir Treatment

By G. R. Stewart and F. E. Hance

Foreword

In a recent conversation with Mr. Greene, manager of the Oahu Sugar Company, we learned that he had considered for some time the employment of a chemical treatment in securing increased impermeability to the natural inside reservoir surface.

Early in 1927, Mr. Bomonti, chemist of the sugar technology department, brought into this laboratory a sample of clay which he had obtained from Mr. Robbins, chemist of the Oahu Sugar Company, at Waipahu. The suggestion was made by Mr. Bomonti that an experiment on the flocculation properties of the clay would be of interest in connection with the possibilities of employing the chemically treated material for lining reservoirs. Independently of the work subsequently carried out in this laboratory, Mr. Robbins has been experimenting with rather extensive chemical clay treatments in its practical reservoir application.

He has conducted numerous laboratory experiments of a quantitative nature in determining the most suitable clay and chemicals to employ in actual reservoir practice.

We wish to make this contribution, therefore, a supplementary one to the pioneer investigations instituted at the plantation of the Oahu Sugar Company.

In studies conducted by soil investigators in various parts of the world, the effects of the salts of sodium on the physical properties of soils have been given considerable attention.

The presence of a high concentration of sodium over other bases, particularly calcium, will produce in a clay soil a condition of compact impermeability, if it later receives a heavy irrigation of fresh water.

Hissink[3] in writing of the effects of ocean flooding on Dutch kwelder soils remarks that as a result of the inundation, the percentage of exchangeable sodium increases and then the soil, when irrigated, will not allow water to readily percolate through.

In a discussion of the reclamations of the salt-injured soils of Arizona, McGeorge[5] points out the futility of any attempt to wash out the large amounts of sodium salts because by so doing the soil "gradually becomes deflocculated and impermeable to water."

The observations of Kelley[4] from his researches on the semi-arid regions of California lead him to state: "One of the important effects produced by the substitution of sodium for the divalent bases is that the granular structure of the clay material becomes broken down with the resulting development of extreme impermeability."

Our experiences in Hawaii[1 and 2] include an additional base magnesium which imparts equal or more impermeable qualities to some of our clay-like soils than does the more common base sodium.

We shall not attempt to go into the theoretical side of the subject in this discussion. That matter has been covered in other contributions with references which appear in the text of this paper. The application of the principle of base replacement can very readily be demonstrated by anyone having access to a glass funnel and a quantity of distilled or high quality tap water. The employment of the principle in sealing a reservoir would suggest itself to one making the experiment as outlined below:

Obtain about one pound of clay-like soil which is known to be sticky, adhesive and impermeable when it is wet. Air dry the soil and powder it as thoroughly as possible by any convenient means.

Place a few ounces of the powdered clay-like soil in a common drinking glass, add about ¼ to ½ ounce of table salt and enough distilled or good tap water to produce a thin paste. Stir the mixture thoroughly and pour into a funnel, the orifice of which has been covered with a plug of moistened absorbent cotton. Allow the excess of water to drain off. Add additional distilled or pure tap water

to the soil mass in the funnel and allow that to drain out. Repeat the addition to and draining out of successive portions of water several times.

It will be noted that the time required for the passage of subsequent additions of water will rapidly reach an interval of long duration. In some cases the passage of water will practically stop even against a 10- or 12-inch head of water in a long cylinder with a funnel outlet.

The conditions now impressed on the soil are known as "freezing" and will persist for a considerable length of time.

The same results will be obtained to a greater or less extent by following the procedure outlined above with the substitution of magnesium sulphate (epsom salts) for the common or table salts which is there specified.

A comparison of the effect of the two salts would determine the better one to use on a larger scale.

In treating a reservoir which is designed to hold mountain water, we would suggest a laboratory experiment to determine the minimum amount of salt which could be employed to "freeze" a known weight of the clay-like material which is available. A coating of 2 to 8 inches in the reservoir bottom should suffice. Having calculated the relative amounts of clay and salt to employ, the materials should be placed in the empty reservoir. Enough mountain water should be added to produce a heavy paste. A mule-drawn drag would materially assist in incorporating salt and clay.

If the reservoir is now partially filled several times and allowed to stand after each filling until leakage has stopped, or at least slowed down, it is ready for use.

As a final mechanical treatment in the last filling, the operation should be so conducted that a thorough agitation of the clay and water is secured.

This operation will assist in securing a maximum dispersion of the clay colloid. It will also insure the deposition of a superficial coating of impervious material on the sides of the reservoir and thus assist in closing up numerous and small porous outlets.

This treatment would prove of little value in the storage of pump water of high salt content.

We feel, however, that mountain or other water of low salt concentration can be impounded with appreciable savings in leakage by treating the reservoirs as herein described.

Summary

This paper deals with a potential process of reservoir sealing by employing the principle of colloid dispersion in clay-like soil lining.

References

1. Hance, F. E. Base replacement in its relation to Hawaiian soils. Reports of the Association of Hawaiian Sugar Technologists, October, 1927.

2. Hance, F. E., and Stewart, G. R. Replaceable bases in the soils of Central Maui. *The Hawaiian Planters' Record,* October, 1927.

3. Hissink, D. J. Base exchange in soils. A general discussion held by the Faraday Society, December, 1924, p. 558.

4. Kelley, W. P., and Brown, S. M. Replaceable bases in soils. Univ. of Cal. Ag. Exp. Sta. Tech. Paper No. 15. Sept., 1924, p. 2.

5. McGeorge, W. T., Breazeale, J. F., and Burgess, P. S. Aluminum hydroxide in alkaline soils and its effect upon permeability. Univ. of Ariz. Col. of Agr. Exp. Sta. Tech. Bull. No. 12, December, 1926, p. 257.

Rate of Cane Growth at Various Ages

By J. A. Verret and U. K. Das

These studies were conducted at Makiki in Honolulu. They were begun in July, 1925. From that time plantings were made every month up to June, 1926. One of the most uniform plots at Makiki was selected for this planting in order to reduce as much as possible the soil variation factor. Moisture conditions were kept at as nearly optimum as could be done. Irrigation was at the rate of 8″ for the first four months and then at the rate of 16″ per acre per month. In order to keep the plant food factor constant all canes were fertilized every month at the rate of 25 pounds of nitrogen per acre; phosphoric acid and potash were put on at the rate of 15 pounds per acre.

Growth measurements were taken from 20 stalks in each planting. During most of the time measurements were made at two-week intervals, others at four weeks. It was originally intended to allow each planting to grow for two years, but when several cases of gall were detected it was decided to harvest the field. From the experiences gained in this preliminary work, we have now started a larger test at Waipio, where not only will growth measurements be taken but areas will be harvested at various ages. At this time the distribution of the roots will be determined by excavation, and the total plant food in the crop will also be determined.

Season Rate of Growth of the Sugar Cane Plant

The records of the growth measurements are given in Table 1 and are charted in Fig. 1. Fig. 1 is based on figures given in Table 1A. The growth curve in Fig. 1 is based on cane 6 to 10 months old, inclusive. Cane of these ages only was used in order to eliminate the age factor in the rate of growth. Cane of these ages had the same number of growth measurements made in all months of the year, the others had not. The growth curve given in Fig. 1, therefore, represents, as nearly as we could make it, seasonal variations only.

TABLE 1

RECORD OF GROWTH MEASUREMENTS IN FIELD E, MAKIKI

Growth for cane planted	Monthly Measurements in Feet: Nov.	Dec.	Jan.	Feb.	Two-weekly period ending: 3/16	3/30	4/13	4/27	5/11	5/25	6/8	6/22	7/6	7/20	8/3	8/17	8/31	9/14	9/28	10/12	10/26	11/10	Four-weekly period ending: 12/8	1/5	2/2	3/2
July 1, 1925	1.01	1.27	1.06	.85	.50	.44	.37	.55	.73	.76	.67	.76	.86	.61	.6[illegible]	.47	.45	.72	.80	.78	.47	.47	.51	.60	.19	....
August	.87	1.18	1.11	1.06	.56	.51	.31	.48	.73	.69	.71	.75	.83	.72	.5[illegible]	.56	.58	.67	.78	.62	.55	.40	.39	.36	.22	.26
September	....	.91	1.08	1.17	.63	.60	.40	.50	.75	.79	.73	.80	.90	.67	.6[illegible]	.69	.75	.75	.71	.47	.30	.51	.34	.36	.35	.42
October	....	....	.85	.94	.63	.57	.39	.53	.75	.79	.64	.85	1.03	.83	.6[illegible]	.70	.76	.74	.72	.50	.47	.47	.34	.39	.38	.36
November	....	....	....	.45	.40	.45	.34	.50	.78	.89	.95	.83	.91	.90	.7[illegible]	.92	.85	.86	.71	.57	.61	.51	.46	.42	.47	.43
December	....	....	....	....	.30	.35	.32	.48	.76	.85	.95	.77	.97	.87	.7[illegible]	.96	.94	1.08	.85	.47	.64	.46	.52	.48	.34	.53
January 3, 1926	....	....	....	....	....	....	.14	.33	.68	.80	1.00	.90	1.04	.92	.6[illegible]	.59	.60	.80	.83	.58	.46	.53	.61	.48	.55	.57
February 1	....	....	....	....	....	....	....	....	....	....	....	.76	.88	.83	.7[illegible]	.74	.74	1.12	.90	.64	.56	.62	.68	.48	.46	.38
March	....	....	....	....	....	....	....	....	....	....	....	....	....	.78	.8[illegible]	.73	.77	.98	.72	.78	.71	.63	.60	.66	.62	.62
April	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.74	.73	.94	.86	.56	.56	.60	.60	.95	.64	.70
May	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.55	.57	.55	.75	1.00	.91	.85
June	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.65	.88	1.00	.81	1.09
Average	.94	1.12	1.03	.89	.50	.49	.32	.48	.74	.80	.81	.80	.93	.79	.7[illegible]	.71	.72	.87	.79	.59	.54	.53	.56	.59	.49	.56
Temperature, °F	75	73	72	72	73	72	68	73	75.5	76	76.5	76.5	78	78	79.5	79	78	79	79	78	77	76.5	74	74	72	71.5

TABLE 1A

Growth records of cane 6, 7, 8, 9 and 10 months old for all months of the year 1926

Growth in feet for	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Age of cane 6 months	1.11	1.17	1.33	.87	1.89	2.10	1.81	1.68	1.92	1.24	1.10	1.27	.....
" " " 7 "	1.06	1.06	1.36	.95	1.93	1.92	1.91	1.65	1.83	1.24	.93	1.12	.....
" " " 8 "	.87	.85	1.18	.97	1.61	1.92	1.84	1.34	2.10	1.64	.86	1.12	.....
" " " 9 "	.99	1.09	1.10	.82	1.67	1.80	1.91	2.05	1.74	1.33	.88	1.05	.....
" " " 10 "	.71	.85	1.19	.95	1.57	1.74	1.80	1.94	2.07	1.15	.92	.74	.....
Average of all ages	.95	1.00	1.19	.91	1.73	1.91	1.86	1.73	1.93	1.32	.94	1.06	16.53
Average (computed from total growth on a 10:4 ratio basis)	.78	.78	1.10	1.33	1.70	1.84	2.02	1.93	1.65	1.38	1.10	.92	16.53
Values for 10:4 ratio	17	17	24	29	37	40	44	42	36	30	24	20	360
Temperature °F	72.0	72.0	72.3	71.6	76.3	76.5	79.0	78.8	78.9	77.0	74.6	74.4	.....

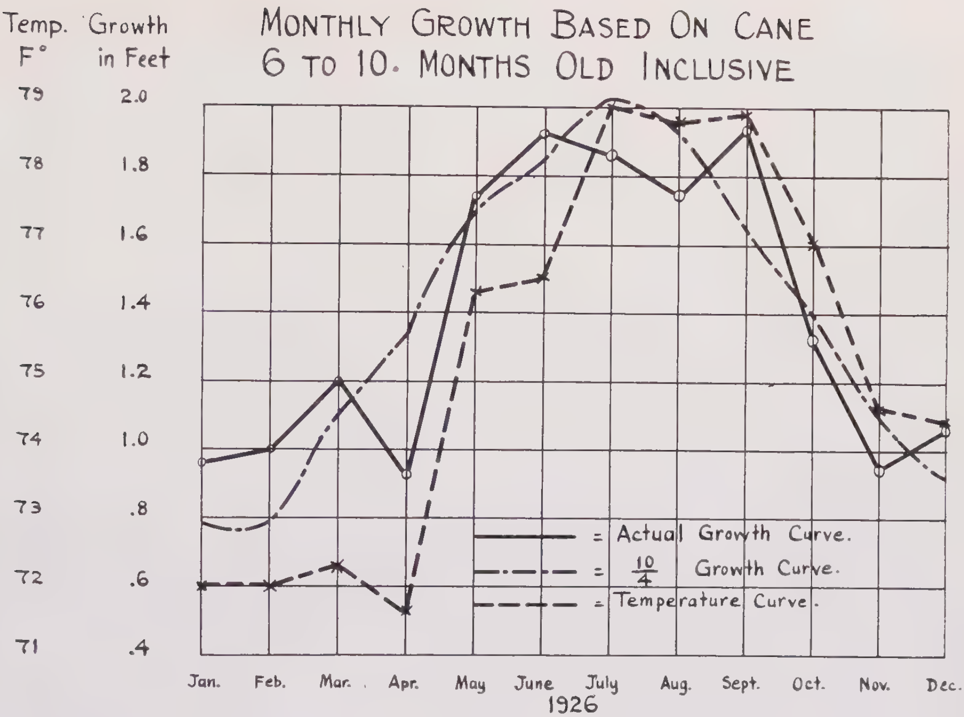


Fig. 1

The Probable Effect of Wind: There appears to be a fair degree of correlation between the temperature and the growth curve throughout most of the period. At places, however, there are certain irregularities. The temperature curve does not vary greatly from July to September, but the growth curve goes down in July and August. Our record shows that on July 8, Field 3 at Makiki was cut, and on July 28 most of the cane in the measurement area was stripped high to facilitate taking measurements. Field 3 was on the mauka side and had served as a windbreak up to this time. By cutting Field 3, the cane in Field 2 was exposed to wind. High stripping probably removed some leaves that were still feeding the stalk and at the same time exposed the cane and the cane rows to the action of wind. Recent experiments at this Station have shown that strong wind retards growth by doing damage to the leaves and under certain conditions by increasing evaporation and perhaps by lowering the temperature locally. The fall in the growth curve between July 6 and August 3 may reasonably be attributed to the effects of stripping and sudden exposure to wind.

The Probable Influence of Daylight: It will be seen from Fig. 1 that up to about the middle of July, the growth curve leads the temperature curve, but from about the month of September the growth curve lags behind. In other words, an increase in temperature gives a large increase in growth up to the middle of July, but from September this increase is comparatively smaller for a given rise in temperature. This may be due to decreasing daylight from July on. The beneficial influence of both these factors, namely, temperature and daylight, were

felt at the same time in spring and early summer. But from August on the favorable effects of an increase in temperature are partially undone by the adverse influence of the decrease in the hours of daylight. That is, the favorable temperature has less time in which to exert its influence. When the temperature goes down in autumn the rate of fall is accelerated by decreasing daylight. Experiments at Makiki have shown that, regardless of temperature, cane makes most growth with maximum daylight.

In addition to the above we believe another factor is acting, tending to cause the plant to make less efficient use of temperature in autumn and winter. In practically all plants, spring and summer is the period of natural fast growth, when the plant is putting on volume; as autumn comes, this tendency becomes less and less and the plant tends towards maturity. This is very marked in annuals, but we feel that even a tropical plant such as sugar cane feels these influences to some extent.

If one smoothed out the growth curve given in Fig. 1 in order to more nearly approach the average seasonal variations, a curve would result which resembles the 10-4 curve suggested by Agee in his "Essential Factors of Sugar Production." The dot-dash line in Fig. 1 is a 10-4 curve. Possibly the values shown for the 10-4 curve are too low for the months of June, August and September. The drop in growth in April is accounted for by the low temperatures and rather strong winds. We have already accounted for the dip in July and August.

TABLE 1B

ELONGATION OF H 109 CANE PER GROWTH DEGREE

FIELD 2—MAKIKI

Period of Growth—From Time of Planting to March 1, 1927

Cane planted first day of	Length of cane in feet		Total growth degrees July:Jan. 10—4	Growth in feet per degree	Total growth degrees July:Jan. 10:2	Growth in feet per degree
1925, July	18.73	(to Feb. 1, only)	575	.033	570	.033
August	18.00		545	.033	530	.034
September	17.72		505	.035	480	.037
October	16.72		470	.036	440	.038
November	16.23		440	.037	410	.040
December	15.83		415	.038	390	.041
1926, January	14.15		395	.036	380	.037
February	12.85		375	.034	370	.036
March	12.52		360	.035	360	.035
April	11.85		335	.035	340	.035
May	10.63		305	.035	310	.034
June	9.03		270	.033	270	.033

In Table 1B we give a study of the rate of cane growth on the basis of Agee's "growth month" method.

In the first column we give the total elongation of the canes planted each month in the year. In the second and fourth columns you find the growth degrees represented by the age of the cane, for both the 10-2 and the 10-4 ratio. The 10-2 ratio means that a unit of growth time in July is given 5 times the value of the same period in January; for the 10-4 ratio it has two and one-half times the value.

In columns three and five we list the growth in feet per degree for the various plantings.

Under ideal conditions, with a perfect ratio, this growth should be the same, no matter when the cane was planted.

Under actual conditions from July, 1925, to July, 1926, we find that this ideal was somewhat closely approached by the 10-4 ratio. The greatest variation was between July, 1925, and December, 1925, where the difference was .005 foot per growth degree or about 13 per cent.

For conditions as they were during this period the values given for the winter months are somewhat too low.

Rate of Sugar Cane Growth at Various Ages

We give the rate of growth of sugar cane at various ages in Table 2 and present the data in graphic form in Fig. 2. These data are preliminary only and further work may introduce some modifications in the growth curve as given, but we feel that the general form of this curve is essentially correct. It may be that the more extensive work will show that the rate of drop in the curve with increasing age will not be quite as rapid as that given in our curve.

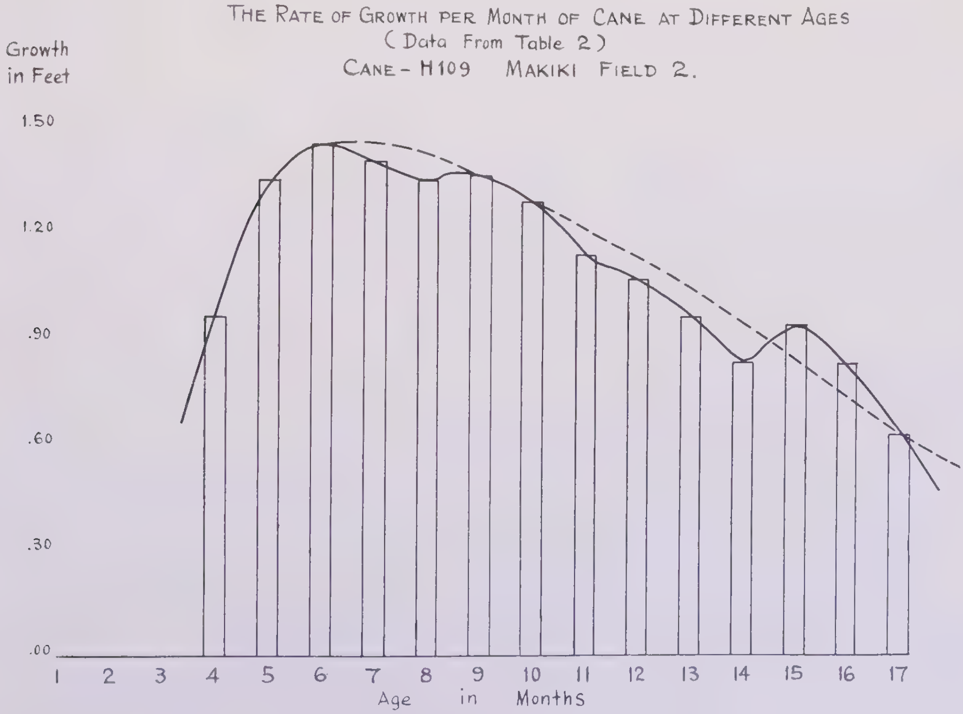


Fig. 2

TABLE 2

GIVING THE GROWTH (IN FEET) AT VARIOUS AGES OF CANE PLANTED IN THE DIFFERENT MONTHS OF THE YEAR

Planted	Age 4 Months	5	6	7	8	9	10	11	12	13	14	15	16	17
July, 1925	.93	1.01	1.27	1.06	.85	1.10	.95	1.59	1.64	1.45	1.05	1.62	1.40	.70
August	.87	1.01	1.11	1.06	1.18	.82	1.57	1.64	1.52	1.26	1.56	1.30	.56	.40
September	.91	1.08	1.17	1.36	.97	1.67	1.74	1.55	1.58	1.56	.87	.60	.40	.38
October	.85	.94	1.33	.95	1.61	1.80	1.80	1.60	1.56	1.09	.58	.43	.42	.36
November	.45	.94	.87	1.93	1.92	1.91	1.94	1.68	1.30	.70	.47	.51	.43	**.55**
December	.72	.83	1.89	1.92	1.84	2.05	2.07	1.24	.70	.53	.37	.53	.73	**.42**
January, 1926	.49	1.83	2.10	1.91	1.34	1.74	1.15	.80	.53	.62	.57	**.83**	**.55**	**.80**
February	1.18	1.76	1.81	1.65	2.10	1.33	.92	.53	.50	.38	**.73**	**.63**	**1.05**	**.89**
March	1.35	1.78	1.68	1.83	1.64	.88	.74	.69	.62	**.84**	**.56**	**1.20**	**1.16**	**.87**
April	1.32	1.79	1.92	1.24	.86	1.05	.71	.70	**.93**	**.64**	**1.06**	**1.32**	**1.13**	**.80**
May	1.18	1.91	1.24	.93	1.12	.99	.85	**.99**	**.71**	**1.22**	**1.11**	**1.29**	**1.05**	**.89**
June	1.35	1.31	1.10	1.12	.87	1.09	**1.19**	**.76**	**1.36**	**1.33**	**1.14**	**1.20**	**1.16**	**.61**
Average (including computed figures)	**.97**	**1.36**	**1.46**	**1.41**	**1.36**	**1.37**	**1.30**	**1.15**	1.08	.97	.84	.95	.84	.64
Average (excluding computed figures)	**.71**	**1.30**	**1.46**	**1.41**	**1.36**	**1.37**	**1.32**	**1.20**	**1.10**	**.94**	**.78**	**.83**	**.62**	**.42**

Note: Figures in heavy type are computed.

The data used in constructing the growth curve given in Fig. 2 comprise measurements made in all months of the year, thereby eliminating the seasonal variation in the rate of growth. As nearly as we could make it, the only variable was age.

The time of most rapid growth for sugar cane is found to be when the cane is from 5 to 10 months old inclusive, being most rapid when 6 months old. After 10 months the rate of growth slows down, and our data tend to show that at 17 months the rate of growth is less than half what it was at 6. Of course this refers to weight only and has no reference to sugar formation. We now have work under way from which we hope to determine the rate of sugar formation in the same way as shown here for weight. The maximum rate of sugar formation will, of course, be later than the maximum for growth.

When a cane joint is first beginning to form it contains starch only, which is used in the formation of fiber. Soon the leaf attached to the joint begins to function and sugars are formed, which are transferred to the joint. A part of these sugars is consumed during growth, the rest is conveyed to the more mature joints. At the moment a joint is full-grown it contains little sucrose and much reducing sugar. From this time on more and more of the sucrose elaborated by the leaf is stored in the joint until the leaf dies off. After this still more sucrose may be stored in the joint, having been transferred from the less mature top.

From this we see that the period of most rapid growth is not necessarily the period of most rapid storage of sucrose, as a great deal of the sugars formed are used to supply energy to the plant.

The Best Time at Which to Plant for the Most Rapid Closing-in

In Table 3 we give the total growth made by sugar cane during the first five months after planting for plantings during all months of the year. We adopted

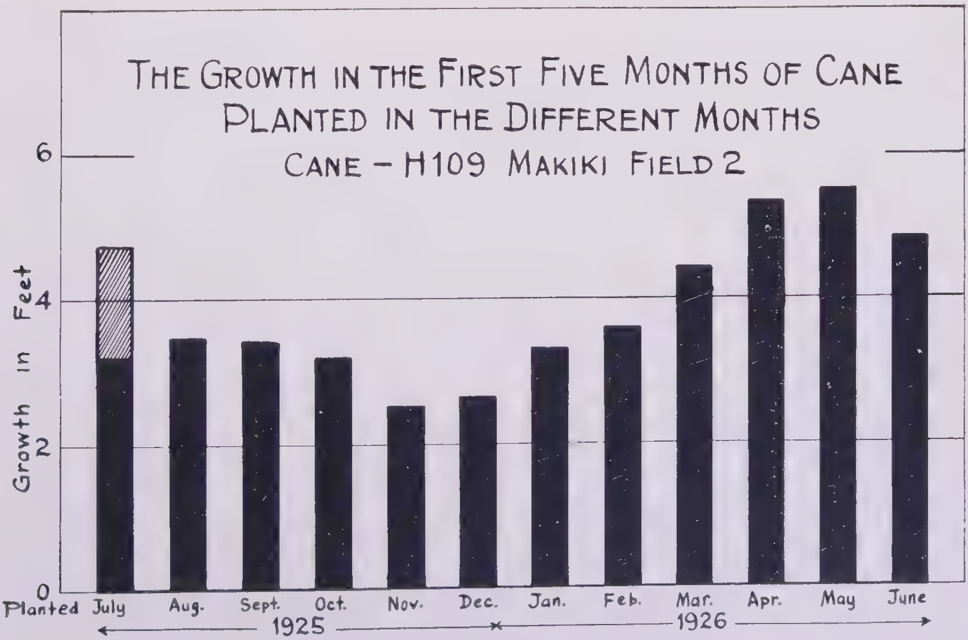


Fig. 3

five months as the period when "millable cane" is beginning to form and the crop fully closed in. The same are given graphically in Fig. 3.

TABLE 3

THE GROWTH IN THE FIRST FIVE MONTHS OF CANE PLANTED IN THE DIFFERENT MONTHS

H 109 CANE, MAKIKI, FIELD 2

Cane planted first day of	Length of cane in feet	Total Growth degrees (July:Jan. 10-4)	Growth in feet per degree
1925, July	3.18 (4.72)	175	.018 (.027)
August	3.51	150	.023
September	3.45	130	.027
October	3.19	110	.029
November	2.57	105	.024
December	2.68	110	.024
1926, January	3.33	125	.027
February	3.63	145	.025
March	4.44	175	.025
April	5.37	190	.028
May	5.50	195	.028
June	4.85	190	.026

In studying Table 3 you will note that the growth in feet per growth degree for cane planted in July, 1925, is only .018 foot, while plantings for all other months show fair uniformity, with the lowest growth at .023 foot per degree. The average for the eleven months, omitting July, is .027 foot. We believe this figure of .018 foot for July to be wrong, and that it would be more accurate to use the average for the other months, namely, .027 foot per degree. On this basis the total growth for the first 5 months for cane planted in July would be 4.72 feet instead of 3.18. This added growth is shown in Fig. 3 by the cross-hatched part of the July column.

These data show that the best months in which to plant in order to obtain the most rapid closing in are March, April, May, June and July. This fully confirms our practical observations.

The poorest months in which to plant are seen to be November and December.

Inoculation Experiments With Sugar Cane Stem Galls

By H. Atherton Lee

The following is a copy of my notes of a series of inoculation experiments to determine the transmissibility of stem gall tissue to healthy cane:

May 20, 1927: Stalks showing young, fresh, actively growing stem galls were taken from stools of U. D. 1, at the Mid-Pacific Institute plots. These galls were from the topmost joints of the cane, still uncolored and protected from weathering by the surrounding leaf sheaths. They were taken to the Manoa substation, taking care to see that they were wrapped well, to avoid spread of infection, if infectious, by handling, etc.

At the Manoa substation, healthy tissue from the top joints of U. D. 1, entirely unaffected with stem galls was macerated with sterile water with a mortar and pestle and was used as an inoculum for controls.

The cane to be inoculated was U. D. 1, never having shown a case of node galls, about 1 year old. Thirty days previously it had received an application of ammonium sulphate to put the cane in a vigorous, actively growing condition.

Twenty stalks of such cane were selected, and the leaf sheaths towards the top split and crowded to the side with a scalpel, allowing inoculation of very young joints near the top of the cane, such joints being newly formed and actively growing. The inoculum of healthy tissue was placed with a sterile needle in the rind tissue of such young joints.

An inoculum was then prepared of the fresh young stem galls collected at the Mid-Pacific Institute, crushing the galls with a small quantity of sterile water in a mortar and pestle. With this inoculum and the same technique as for the controls, young, newly formed nodes of 20 additional stalks of U. D. 1 were inoculated. A sterile needle was used to puncture the cane rind and introduce the crushed tissue of the inoculum. The leaves and leaf sheaths of the cane stalk were then allowed to push back over the inoculated node, maintaining natural moisture. This moisture was supplemented by wet cotton and the whole top of the inoculated stalk was then wrapped in paraffin paper and then opaque newspaper to maintain moisture and exclude sunlight.

The results of such inoculations follow:

Stalk No.	Inoculum	Result	Date
1	Crushed healthy cane tissue	Negative	June 21
2	" " " "	"	July 26
3	" " " "	Negative(a	July 26
4	" " " "	Negative(a	June 21
5	" " " "	Negative	July 26
6	" " " "	Negative(a	June 21
7	" " " "	Negative	
8	" " " "	"	July 26
9	" " " "	"	July 26
10	" " " "	"	July 26
11	" " " "	"	July 26
12	" " " "	"	July 26
13	" " " "	Negative(a	July 26
14	" " " "	Negative	June 21
15	" " " "	"	July 26
16	" " " "	"	July 26
17	" " " "	"	July 26
18	" " " "	"	July 26
19	" " " "	"	July 26
20	" " " "	"	July 26
21	Crushed stem gall tissue	Negative	June 10
22	" " " "	"	July 26
23	" " " "	"	July 26
24	" " " "	Negative(a	June 10
25	" " " "	"	June 10
26	" " " "	"	July 26
27	" " " "	"	June 21
28	" " " "	Negative	July 26
29	" " " "	"	July 26
30	" " " "	"	July 26
31	" " " "	Negative(b	July 26
32	" " " "	Negative	July 26
33	" " " "	"	July 26
34	" " " "	"	July 26
35	" " " "	Negative(b	July 26
36	" " " "	Negative	July 26
37	" " " "	"	June 21
38	" " " "	Negative(a	June 21
39	" " " "	Negative	July 26
40	" " " "	"	July 26

(a—A slight scarcely noticeable formation of callus occurred on the rind tissue surrounding the inoculation puncture; it could not be considered a stem gall.

(b—A slight nub or swelling occurred in the rind in the position of the meristematic tissue just above the root band; such swellings could not be considered stem galls; they also occurred on uninoculated stalks.

Conclusion: The results of this experiment are as definitely negative as could be expected in any experimental work. They lead to the feeling that if stem galls are infectious, transmission must be made by insect vectors. Another possibility that begins to appear promising for investigation is the relationship of insects as direct producers of such proliferating tissue.

July 29, 1927.

Hot Water Heated Propagating Benches

By R. E. Doty

The work of the seedling season of 1925-1926 demonstrated that bottom heat was effective in securing a good germination of cane fuzz during the winter months.

During the past season, 1926-1927, a series of hot water heated benches were developed. Two types were built and operated very successfully during the entire season. The first type, which was constructed in the open, was equipped with a cloth cover for rain protection; the other type was built without a cover to be used only in a glasshouse.

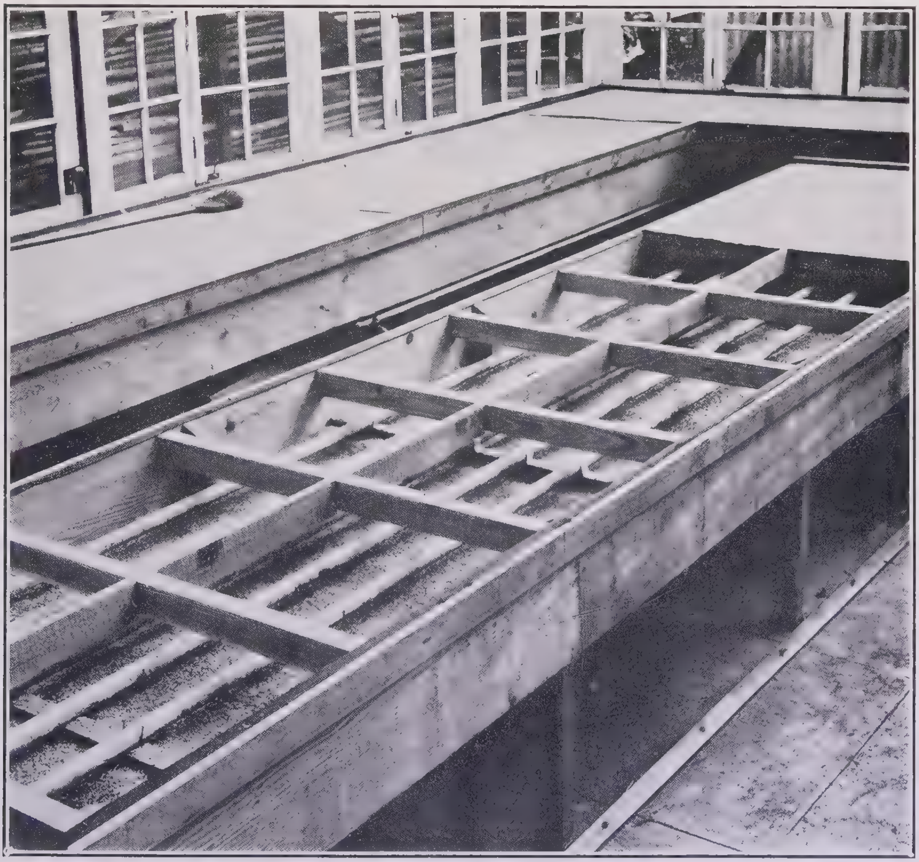


Fig. 1. Hot water heated glasshouse propagating bench. This illustration shows the general method of single wall construction for inside benches. (Outside benches differ in that they have a double side wall, heated pipes placed with a slight fall [1″ to 20′], and a cover for rain protection.) The bottom of the bench is covered with rice hulls. The heated pipes are resting on 2x3 cross pieces. The iron cover or plate is shown at the extreme right.

Construction

Each of the outside benches consists of a large boxed air chamber containing coils of hot water pipes, covered by sheets of galvanized iron, through which the heat from the air around the pipes is transmitted to the bottoms of the seed flats. This hot air chamber is approximately 4 feet wide, 32 feet long, and 10 inches deep. The framework is made of 2″x3″ material. The bottom is constructed of 1″x6″ tongue and groove. The sides are double walled; a 1″x12″ on the outside and a 1¼″x10″ on the inside with a 1½″ space between. The upright supports (2″x3″) come up into this space and hold the outside and the inside boards in place. The floor is notched around these 2″x3″ to make a tight fit. This space is filled with dry rice hulls. A two-inch layer of rice hulls also forms excellent insulation for the bottom of the hot air chamber. Old bagasse board and asphalt sheathing are also good as insulating materials. (See Fig. 1.)

The heating unit consists of four lines of 1¼″ galvanized pipe placed inside of the bench and running its entire length. This pipe is connected in one continuous line, coiled so that the pipes are equidistant from each other and from the side wall. The intake pipe enters the end of the box about 1¼″ down from the sheet iron cover and the coil is adjusted and blocked to give a slight fall, about 1½″ to each length of 32 feet of pipe. This allows the return pipe to leave through the end of the hot air chamber very near the bottom. This method of laying the pipe in the hot air chamber is an aid to the hot water circulating system. The return pipe also runs next to and parellel with the intake. This equalizes the heat throughout the air chamber, as the cooler return pipe is next to the hot intake.

In one bench, six lines of 1″ pipe were used. In this case extra strips of tin and iron were wired to the pipes to form radiating fins to help release the heat more rapidly from the pipes to the air. (See Fig. 2.)

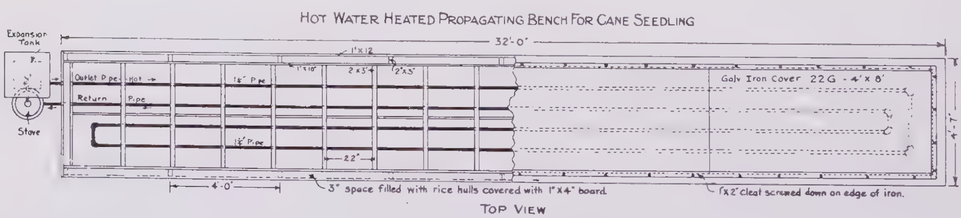


Fig. 2

After the heating pipes are in place, the benches are covered with sheets of 22 G. galvanized iron on which the seed boxes are to be placed. This iron cover is supported and held level by cross joists (2″x3″) which are placed directly over the pipes, and spaced every 22 to 24 inches. The edges of the iron sheets are lapped directly on one of these joists. To make a rather tight fit between the iron and the wood edge of the air chamber, strips of asphalt felt paper are placed between the iron and the edge of the 1¼″x10″ side board. This edge is held down snugly by a ¾″x1″ strip screwed down with No. 9 1½″ wood screws. The

screws are placed slightly away from the edge of the iron to allow sufficient space for expansion of the iron when heated.

Covering

The simplest arrangement for covering the benches is to construct a gable-roofed frame of 1″x4″ material and cover with cloth.

Strips of unbleached muslin (waterproofed with paraffin dissolved in gasoline) are fastened to this frame at the top. The bottom of this strip of cloth is fastened to a wood strip (1″x3″) to form a rolled drop-curtain. This curtain can be rolled up to the top of the frame in good weather or dropped down, to form a complete cover over the boxes, in rainy weather. During the night this cover also serves to hold the heat which is constantly radiating from the surface of the soil in the flats.

Heating Apparatus

Having constructed a satisfactory bench, it is then necessary to decide what source of heat should be used. The experimental work was done entirely with a Perfection 2-burner blue chimney kerosene hot water heater. (See Fig. 3.) This stove is commonly used to heat a water tank in dwellings. It has capacity sufficient to heat one large table 4′x32′. After constructing four large outside benches, and with the possibility of building still more in the future, there was some thought of installing a low pressure hot water boiler to burn fuel oil. One boiler of this type would care for a goodly number of seedling propagating benches. But it was finally considered better to use kerosene heaters so that much smaller units could be operated independently.

In order to give positive circulation with a gravity circulating hot water system, it is necessary to have the expansion tank directly above the stove. This tank is open at the top and allows the escape of air or steam from the hot water without getting into the heated coils. In the first bench this tank is a 5-gallon oil can packed in a box with a 2″ layer of filter-cel insulation around the sides and bottom. The hot water rises through the coils of the stove and arrives in the tank at the highest temperature as well as at the greatest height in the water circuit. From a point on the side of the tank the water is conducted through a pipe into the table and on through the coils. These coils have about one inch of fall for every 20 feet of pipe. The water continually cools as it travels through the coils, finally arriving at the bottom of the stove again to be heated and again circulated. This water will make one complete circuit in about twenty minutes, starting with a tank of hot water, a good flame, and cold return water.

Heat may be applied to three benches in series by the following method:

Two large sized (No. 421) Perfection kerosene hot water heaters are installed together in a specially built 5′x6′ house. (See Fig. 4.) Both stoves are connected to the same expansion tank, which is placed in the roof directly over the stoves. This tank is kept full of water by means of a city water connection, controlled by a ball and cock float valve of a design commonly used in toilet tanks. The hot water

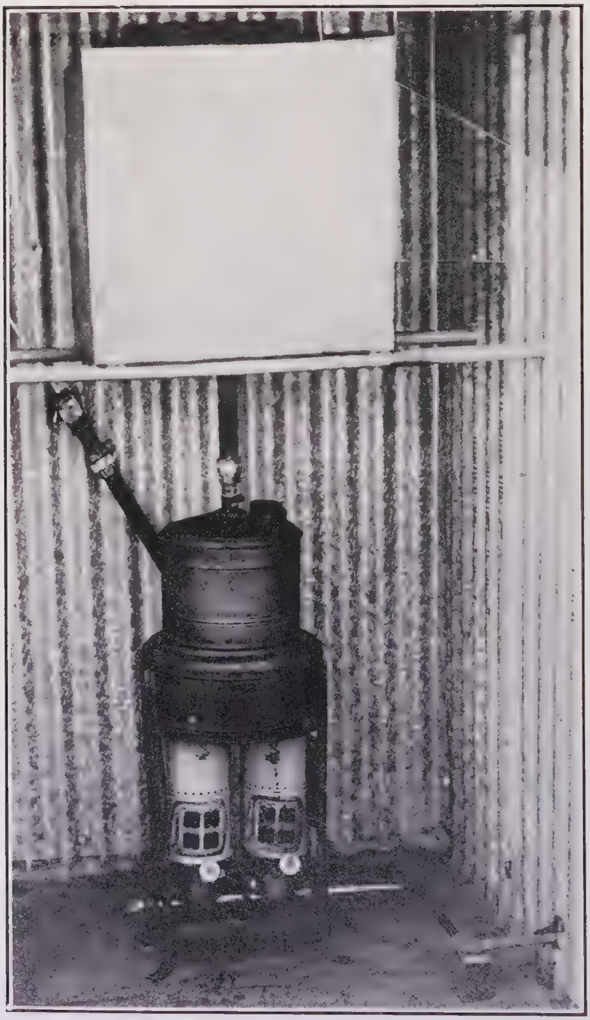


Fig. 3. A Perfection two-burner stove used to heat one 4'x32' outside propagating bench for cane seedling work. Note that the oil tank is outside the wall to reduce fire hazard, as this type of stove does not have a thermostatic cut-off. Oil feed pipe shown at lower right. Expansion tank is shown directly above the stove. Stove house constructed of corrugated iron.

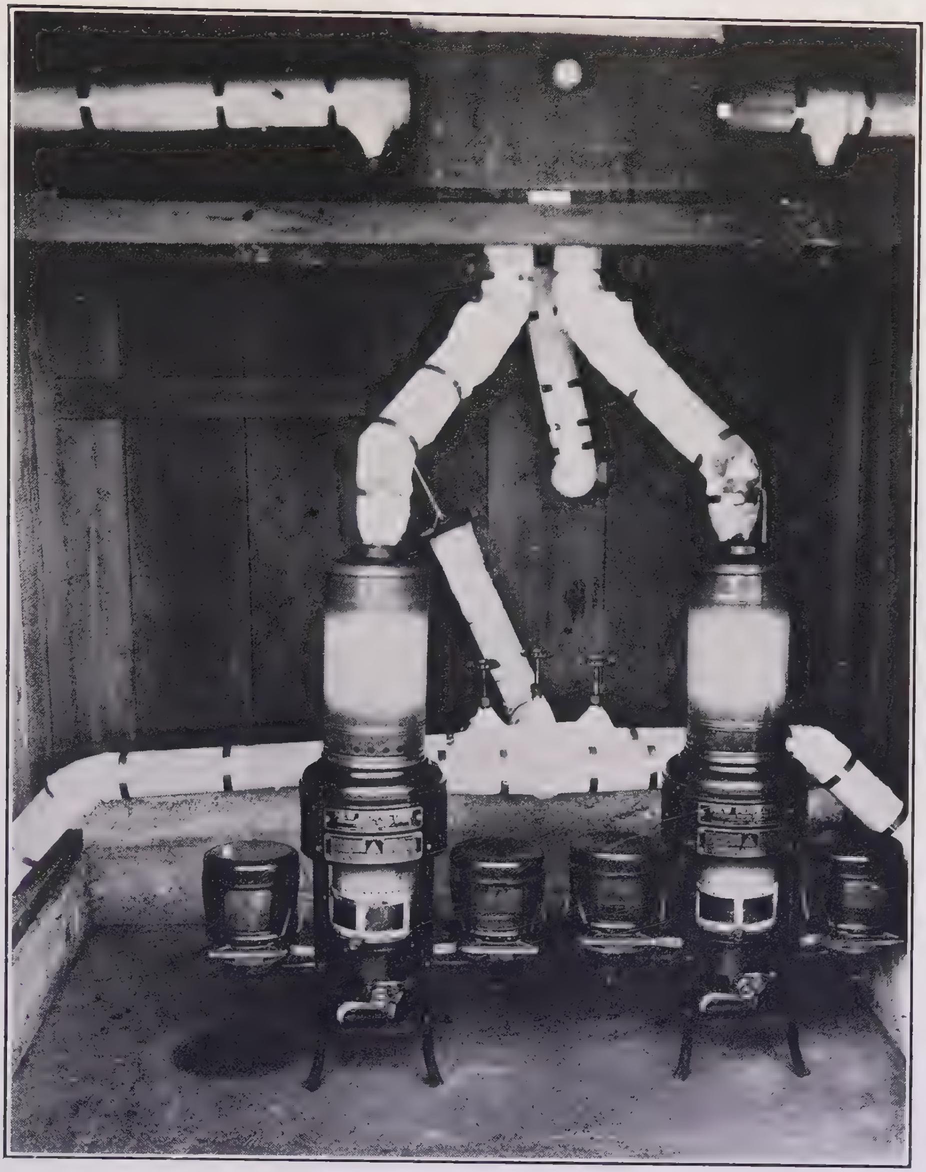


Fig. 4. A two-stove gravity circulating hot water heating unit. These stoves operate three outside propagating benches, each bench 4′x32′x10″. The cooler return water coming from the three benches enters the stoves at the lower end of the stove coils and the heated water rises to the expansion tank directly over the stoves. Here it is led by three outlet pipes to the bench coils (two outlet pipes shown). Note valves on outlet and return pipes to give flexibility in operation. One or both stoves, one or more benches may be operated alone.

pipes from the three benches are connected to this tank and the returns brought back to the bottom of the stoves. By means of valves on the outgoing hot water lines and the return lines, it is possible to operate one, two or three benches, and one or both stoves at will. This gives great flexibility in operation. All piping in this installation is of 1¼″ galvanized. Unions are put in all connecting lines between the stoves, tank and benches, to enable repairs or changes to be made easily. All exposed pipes are lagged with magnesia pipe covering and then covered with roofing paper. The return pipes from the three benches are brought to a central point back of the stoves and joined by means of proper bushings to a 2½″ double cross tee. Then two lines, one to each stove, are taken from the cross tee. This equalizes the flow and temperature of the water to each stove. A thermometer is placed through a rubber cork in a tee on the return line from each bench to check the temperatures of the return water. With the valves open and the same number of seed flats on each table, the temperature difference between the three thermometers is less than 2° F., with the water at 170° F.

Glasshouse Benches

Two large U-shaped benches were built in the glasshouse this season. They were made slightly narrower (42″) than the outside benches to make the best use of space. One bench was built close to the wall on three sides of the glasshouse. This bench was about 90′ long.

A gas hot water heater and a "Duro" pump of 80 gallons per hour capacity, which were on hand at the Station, were used in the first installation. It was not practical to try to make this system circulate by gravity, due to the great length of this bench, so the pump was a necessity.

The general construction of these benches followed the plan of the outside benches, except double side walls were unnecessary. Any heat that radiated through the side would be useful in raising the temperature of the air in the glasshouse.

The iron used for the top was 24 gauge, 42″ wide instead of 22 G. 48″ wide, being both narrower and lighter in weight.

As this system was operated by a pump, six lengths of 1″ pipe were used for the heating coils instead of 1¼″.

When the second bench was built in the glasshouse, it was necessary to use a larger pump and have an auxiliary kerosene heater installed in the circuit to heat both benches properly. By connecting the return pipes from each bench to both pumps, the water of both benches can be maintained at the same temperature. (See Fig. 5.)

Operation of Heated Benches

Oil Burned

The stoves to heat the benches burned kerosene oil. The small 2-burner stove operating one large outside bench burned one gallon of oil in 9 to 10 hours, depending on the height of flame.

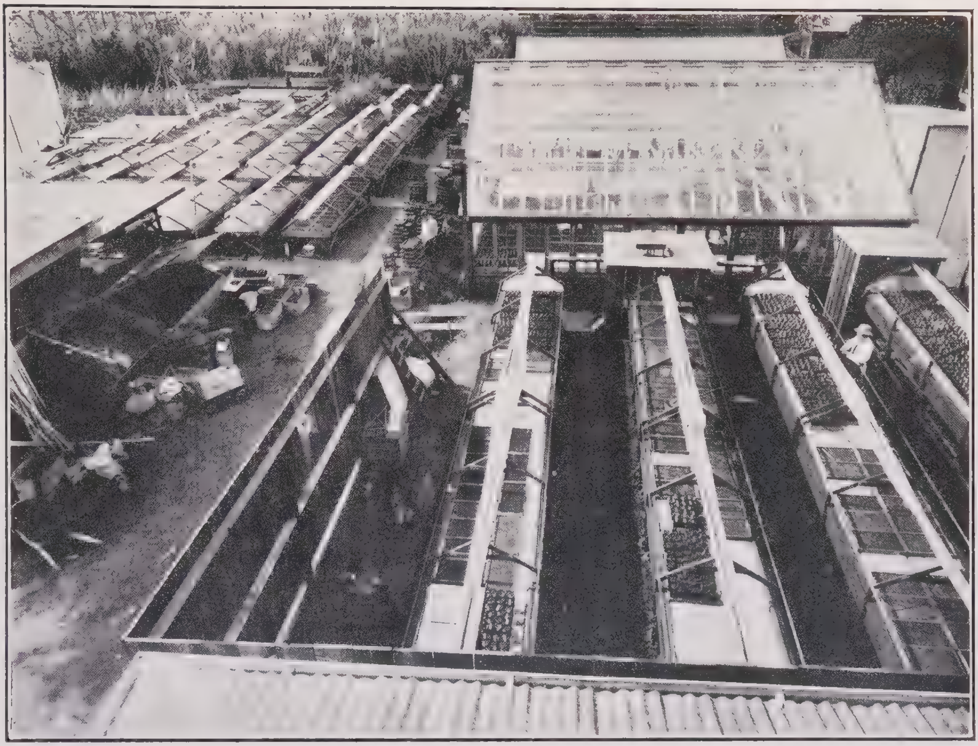


Fig. 5. General view of seedling work, 1926-1927. Hot water (kerosene units) used for heating benches in foreground and in glasshouse.

The large super flex burner stoves (No. 421 Perfection) burned one gallon in 8 to 10 hours, depending on the height of flame. Two of these stoves operated three large outdoor benches.

Temperatures Obtained

These benches were operated for approximately four months (December to March). During cold and cloudy weather the stoves were kept going at varying flames during the day, according to the amount of sunshine. The burners were turned up full at four o'clock in the afternoon and turned low again at eight o'clock the next morning. This kept the water warm at all times. During warmer weather the stoves were turned out at 8 a. m. and turned on again between 3 and 4 p. m.

Temperature records were kept for each table recording the temperature of the hot return water, and the reading of one or two thermometers on top of the soil in the flats. These readings were taken every two hours, beginning at 6 p. m. and continuing until 8 a. m. each day. These records were kept for several weeks and gave information as to the fluctuations occurring during the night.

The hot water from the stoves generally entered the expansion tank at about 205° to 210° F. The return water would be cooled down to between 170° to 180°, depending on the outside atmospheric temperature. On an average night,

when the return water was 175° F., the temperature of the fuzz under the waxed paper would be about 87° or 88° F. On very cool nights (50°-65°) the fuzz temperature would be lower for the given water temperature and the reverse would be true on warmer days.

In order to visualize the differences in the temperatures of the heated seed boxes and the outside air at night, the following brief table is inserted here. This table gives the average monthly mean minimum temperature for the months during which the heated benches were operated:

Month	Mean monthly minimum	Lowest temperature recorded at night
December, 1926	64.71° F.	58° F.
January, 1927	64.32° F.	58° F.
February, 1927	60.86° F.	50° F.
March, 1927	64.94° F.	59° F.

During these months the temperatures at night under the paper were maintained from 86° to 92° F. There was a remarkable uniformity in the temperatures throughout the night for a given flame height of a stove. A bench that was running at 88° F. would not vary over 1° during the night. If there was a drop in temperature, it generally occurred at the 4 a. m. or 6 a. m. reading. The temperature rarely reached 94° F. It was practically impossible to overheat the benches unless there was full sun as well as artificial heat.

After the young seedlings have germinated, it is the standard practice to remove the wax paper. This removal of the wax paper causes a drop of 8° to 10° F. in the flats on the outside benches. Windy weather causes the temperatures to drop in all outside benches, though it makes little difference in the glasshouse.

Under this system of bottom heat and the wax paper covering over the fuzz, germinations occur regularly on the morning of the third day after planting. The shortest time that we have on actual record is forty hours. This was obtained by planting at 4 p. m. on a given day and examining the flats at 8 a. m. on the second morning following. Germinations were numerous, and large enough to be easily seen.

Seed Flats With Sheet Iron Bottoms

A study was made of the types of seed flats best adapted to transmit the heat from the hot iron cover of the heated benches to the soil in the seed flat.

A sample lot of seed flats were made, having the following differences:

1. Normal ⅜″ wood bottoms,
2. 1″ sand screen or chicken wire with burlap bottoms, and
3. Galvanized sheet iron (28 G.) bottoms with drainage holes.

These three types of boxes were placed on a heated bench and temperatures were taken at intervals over a period of two days. These tests showed that the flats having sheet iron bottoms heated up more rapidly and, for a considerable period, maintained temperatures about 2° F. higher than the boxes having wood bottoms. If the heat was applied for five or six hours or more, the temperature of

the soil in the boxes having wood bottoms would eventually be the same as the soil in the boxes having iron bottoms.

The boxes having various forms of wire mesh bottoms and burlap, heated up almost as good as the iron bottomed boxes. But the great defect of this type of box was the sagging of the bottom while being carried from one place to another. The weight of the soil invariably sagged the bottom so that, when the box was placed on a level bench, large cracks appeared in the surface of the soil. These cracks undoubtedly cause the death of many seedlings. The box with the sheet iron bottom with drainage holes was adopted as being the best for applying artificial heat.

Some Notes on the 1926-27 Seedling Work

By J. A. Verret, A. J. Mangelsdorf and C. G. Lennox

On Preserving Cane Stalks

Layering

In a recent paper by Venkatraman and Thomas*, a method is described whereby cut tassels are kept alive in the following manner: The roots on a portion of the stalk just above the ground are induced to develop by surrounding this portion with soil which is kept moist. The work is done at the first indication of tasseling, so that there will be ample root development by the time it becomes necessary to isolate the tassel. Just before blooming begins the stalk is cut at a point below the "layer" and the stalk is thereafter kept alive by the roots within the layer.

This method was given rather an extensive trial the past season. Instead of soil a "layer" of sphagnum moss was used. It was held in position by wrapping it with a bandage of cotton cloth dipped in paraffin to prevent the absorption of water and subsequent loss through evaporation. The "layer" was kept moist with water and with dilute nutrient solution. It was found that rooting took place more readily at the upper part of the stalk where the cane was not so hard. Considerable difference was observed in the length of time required by different varieties to send out roots.

Whenever a sufficient amount of root development had occurred previous to cutting, the stalks treated in this way remained as fresh as though still attached to their original roots. Where the number of roots in the layer was limited, a certain amount of wilting and premature dying occurred.

The method has this disadvantage: the layer must be applied some weeks before tasseling and it must be kept constantly moist thereafter. This requires consid-

* Isolation of live arrows from undesired pollen through artificial rooting of canes. T. S. Venkatraman and R. Thomas, *Ag. Jour. of India*, Vol. XXI, Part III, May, 1926.

erable labor. Meanwhile the layered tassels may be rendered unfit for use by the high winds which may be expected at that season. Furthermore, it is difficult to anticipate in advance just how many tassels of each of the varieties will be required.

At the present time the method appears to present a number of disadvantages and few advantages as compared to the sulphurous acid method.

Supplying Water Under Pressure

Proceeding on the assumption that the wilting of cut tassels is due to their failure to take up water rapidly enough to maintain turgidity, an attempt was made to increase the water intake by supplying water under pressure. This was accomplished by connecting the cut ends of the stalks by means of rubber tubing to a pipe line in which a pressure of four pounds per square inch was maintained. Without considering resistance, this amount of pressure is sufficient to raise a column of water to a height well above the tops of the tassels. The cut midribs of the leaves did, in fact, exude water, indicating that the pressure was effective. Five tassels were thus treated, while five tassels placed in jars of water and five in jars of .03 per cent sulphurous acid served as checks. The tassels supplied with water under pressure bloomed more normally and lived longer than those in water without pressure, but neither succeeded as well as those in the sulphurous acid solution.

Sulphurous Acid

Two strengths of sulphurous acids, .015 and .03 per cent of SO_2 respectively, were tried rather extensively in comparison with each other during the past season. The stronger solution gave the better results. Indeed, nothing has thus far been found which is superior to a .03 per cent sulphur dioxide solution for keeping cut cane stalks alive and fresh.

Indoor Crossing

A method of crossing which was given an extensive trial the past season with but little success is the following: The female tassels were kept in canvas houses in which a high humidity was maintained by constant spraying. It was thought that the reduced transpiration in these so-called "humid houses" should help to prolong the life of the cut tassels.

The male tassels were kept in other houses under ordinary atmospheric conditions and were so placed that their pollen, when shed, would fall upon sheets of glazed black paper. The pollen was then carried to the humid houses and dusted upon the female tassels.

The percentage of germination obtained in this way was very low. It is probable that there was a certain amount of loss of viability of both pollen and stigmas due to our inability to get the pollen to the stigmas promptly enough. It is also possible that the reduction of transpiration in the humid houses is actually detrimental, since it cuts down the volume of the stream of sap passing upward in the stalk and therefore also the flow of nutrients from the stalk to the tassel.

Emasculation of Cane Tassels

A problem sometimes encountered in the crossing work is that of obtaining crosses between two varieties, each of which is self-fertile. One method of attack is to place the two varieties together and to rely on the hope that in addition to the seedlings resulting from selfing a percentage of crosses will also be found.

Another possibility is to remove the anthers from one of the varieties before it has shed its pollen, using it as the female parent. Castration by hand, however, is so laborious as to be impracticable. A few preliminary experiments were carried on this season on removing the anthers by means of suction. The suction hose of a vacuum cleaner was equipped with a glass tube drawn to a diameter just large enough to permit the ready intake of the anthers. It was found that the tassel could be gone over quite rapidly by this means. The efficacy with which the anthers are removed depends on how well they are extruded and this depends more or less upon the variety. In some varieties the anthers remain partially enclosed by the glumes and their removal by suction when in this position is difficult.

The method has no place except in special cases where the self-fertility of each of the two parent varieties is so great as to seriously reduce the percentage of crossing.

Heating of Germination Tables

A method of heating which has been tried out the past season is the following: the germination table, which is 8 feet long and 4 feet wide, is constructed entirely of metal. The legs and cross pieces are 1¼ inch iron pipe, while a piece of sheet iron (22 gauge) serves as the top. A layer of soil of the usual depth is placed directly upon the sheet iron so that we actually have what amounts to a large seedling flat 8 feet long, 4 feet wide and 2 inches deep, with a metal bottom. The source of heat is an inexpensive kerosene stove placed directly beneath the center of the table. The heat is diffused as much as possible by means of a baffle plate of sheet iron, 2 feet square, suspended horizontally immediately above the heater. The heat is confined beneath the table by means of cotton sheeting which goes entirely around the sides except for a door 2 feet wide immediately in front of the stove. This door, which affords easy access to the stove, is closed by means of a drop curtain.

The construction of such a table is fairly cheap and very durable, and the method of supplying heat is simple. The heat distribution, while not as uniform as might be desired, is fairly good. While not as desirable as a hot water installation, it gives decidedly better results than an unheated table.

Pollen Producing Capacity of Various Canes

In planning the season's crossing program it is helpful to have at hand information concerning the pollen producing capacity of the varieties to be used. The amount of pollen produced by a given variety determines to a large extent whether that variety can be most advantageously used as a male or as a female

parent. The characteristic is known to vary with environmental conditions, but on the whole it is remarkably constant.

Observations on this point on some of the more important varieties handled during the past season are listed below:

Variety	Pollen	Variety	Pollen
Badila	Abundant	Makaweli 3	Abundant
25 C 4	Abundant	Mexican Bamboo	Scanty
25 C 7	Scanty	P. O. J. 36	None
25 C 8	None	P. O. J. 213	None
25 C 21	None	P. O. J. 234	None
25 C 30	Fair	P. O. J. 979	None
25 C 31	None	26 Q H 1	Abundant
25 C 40	Scanty	26 Q 534	Abundant
25 C 46	None	26 Q 562	Abundant
D 117	Abundant	26 Q 1079	Fair
D 1135	Fair	Red Tip	Scanty
H 27	Abundant	Rose Bamboo	Scanty
H 109	Fair	Striped Mexican	Scanty
H 146	Scanty	Striped Tip	Scanty
H 227	Abundant	20 S 16	Abundant
H 456	Abundant	Tiboo Mird	Scanty
H 8965	Abundant	Uba	None
H 9802	Scanty	U. D. 1	None
H 9811	Fair	White Bamboo	Fair
Keni Keni	None	Wailuku 9	Fair
Lahaina	None	Waipahu 122	Scanty
Lahi	Abundant	Yellow Caledonia	None
Makaweli 1	Fair	Yellow Tip	Scanty

Fertility of Uba Seedlings

So far as they have been observed the first generation Uba hybrids have proved to be quite male-sterile, that is, they produce no good pollen. Only one exception has been found thus far,—U. D. 50 appears to be slightly male-fertile.

Observations were made the past season on the Uba quarter-breeds (26 Q series) resulting from crossing the first generation hybrids (half-breeds) back to the big-sticked canes. The pollen fertility in this generation is somewhat increased but there is still a high degree of sterility. About one seedling in five produces some pollen and only about one in fifty produces it in abundance.

The Uba quarter-breeds must therefore be used for the most part in crossing as female parents. Those producing enough pollen to serve as male parents are the exception.

Treatment of Fuzz to Reduce Its Bulk

Some of our most desirable parent varieties give extremely poor germinations, necessitating the planting of a large amount of fuzz in order to obtain even a few seedlings. A method whereby the volume of the fuzz could be reduced would result in considerable saving of space, labor and expense. A means of separating

the kernels from the surrounding glumes and from the sterile seeds, would be desirable, possibly something in the nature of a miniature threshing machine. However, the difficulties in the way of threshing a material like cane fuzz are obviously very great.

A few preliminary experiments indicate that dipping the fuzz for one minute in concentrated sulphuric acid and washing immediately on a fine meshed wire sieve under a stream of water cuts down the bulk of the fuzz quite materially. The percentage of viable seeds is apparently slightly reduced by the treatment, but the rate of germination is more rapid, the treated fuzz germinating one to two days ahead of the untreated checks. The fuzz must, of course, be planted immediately after treating.

Treatment of Fuzz After Planting

After the fuzz has been planted and previous to its germination, some means of covering the flat is desirable to prevent so far as possible the evaporation of moisture and the cooling which accompanies it. Waxed paper serves the purpose very well in the greenhouse, but it is too easily blown about on the outside tables. Glass panes partially shaded with whitewash are satisfactory, but they are expensive and breakable. A suitable material, except for its rather high price, is Celoglass, a glass substitute made by coating wire screen with a celluloid-like substance. It may also be used for the construction of hotbed sash. It has an additional advantage in admitting a considerably larger percentage of ultra-violet rays than does ordinary glass.

Seedlings for Eye Spot Areas

With the cooperation of the pathology department, seedlings intended for eye spot areas are subjected to a preliminary elimination while still in the flats by spraying them with an infusion of eye spot spores. Practically all of the seedlings develop the disease, and many of them succumb very quickly to its effects. A few, however, show a high degree of tolerance. It is reasonable to suppose that the survivors will on the whole be more resistant than the average of the lot before treatment.

Effect of Wind on Cane Growth

By J. A. Verret and R. H. McLennan

In this test we endeavored to determine the effect of moderate wind on cane growth. The wind effect was produced by means of 16-inch electric fans, each plant having a fan blowing directly upon it. We did not have the instruments, so the wind velocity was not determined. The wind was not of such force as to cause appreciable physical damage to the cane leaves. The plants were grown in

16-inch concrete pots and in large galvanized iron tubs. Every effort was made to have plants of the same size at the start. All the seed pieces used were of the same size and weight.

We conducted two series of experiments. In one series the same amount of water was used in all pots, fan and "no fan." We tried to regulate the amount of water so as to give optimum moisture to the "no fan" pots.

In the other series we weighed the pots each day and replaced the evaporated water. In this way all pots were kept at a moisture content of 25 per cent on the dry basis.

Constant Moisture Series

In the constant moisture series we used twelve 16-inch pots. Six of these were exposed to the wind effect from six 16-inch fans. The remaining six pots were used as controls. All pots were kept in the greenhouse in order to control the moisture. The surfaces of the pots were kept covered in order to have a more uniform moisture content in all pots. During the course of the experiment one of the "no fan" plants became diseased and made very poor growth compared with the others. It was therefore discarded.

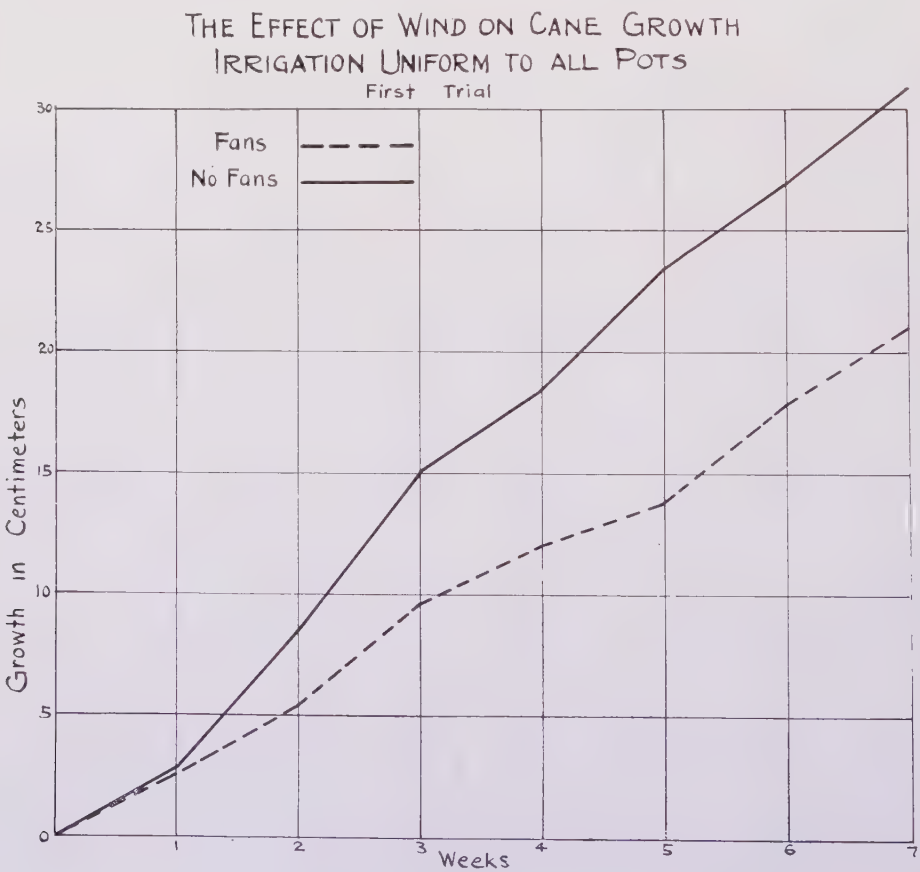


Fig. 1

The results obtained are summarized in the following table:

	Total No. of shoots*	Avg. height of primary shoot	Green weight of plants	Per cent loss in weight
Fans	16	7.9	22.3 ounces	14
No Fans	11	7.2	26.6 ounces	

These results, for the condition of the experiment, would indicate that the fans tended to increase stooling in the ratio of 16 to 11. The average length of the primary shoots was also somewhat more for the fan pots, but the total green matter produced was 14 per cent less in the fan pots. The shoots in the fan pots were smaller in diameter than were those in the "no fan" pots. We do not know whether the increased stooling noted in the fan pots is significant or not. The small number of plants involved introduce a large probable error. Also, on account of the small size of the pots, the plants were becoming pot bound so the test was stopped at the end of 56 days. Had the test continued longer the plants in the "no fan" pots might have stooled out later. The extra stooling in the fan pots may have been caused by the constant shaking of the plants. This loosened the

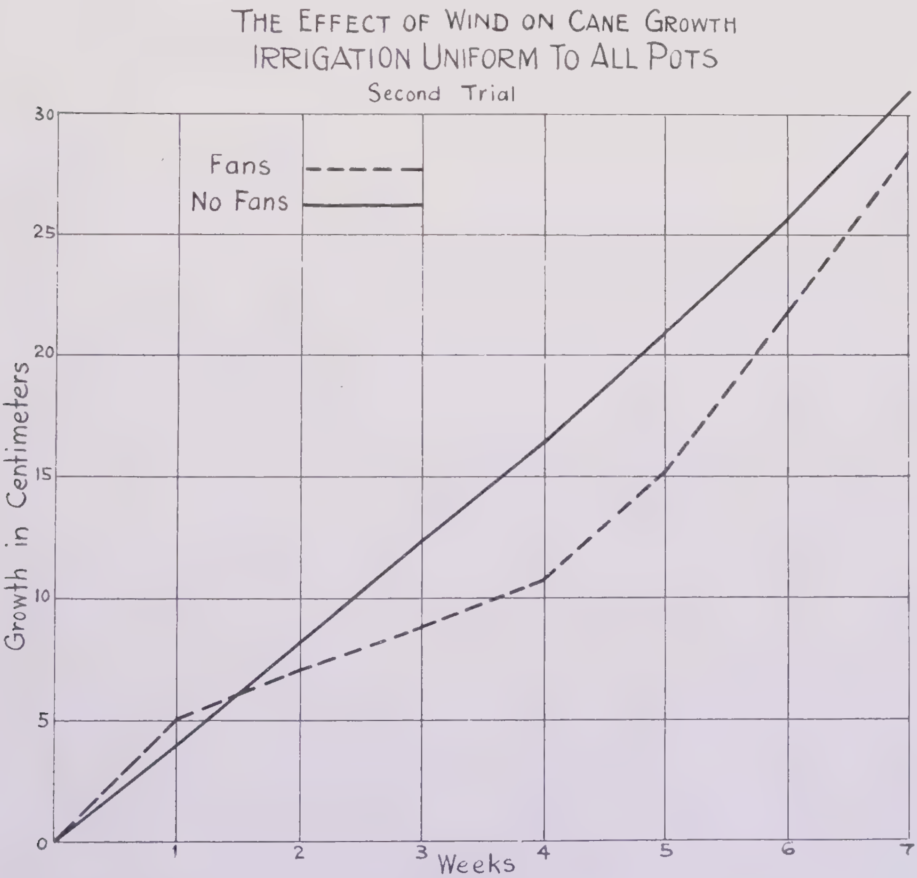


Fig. 2

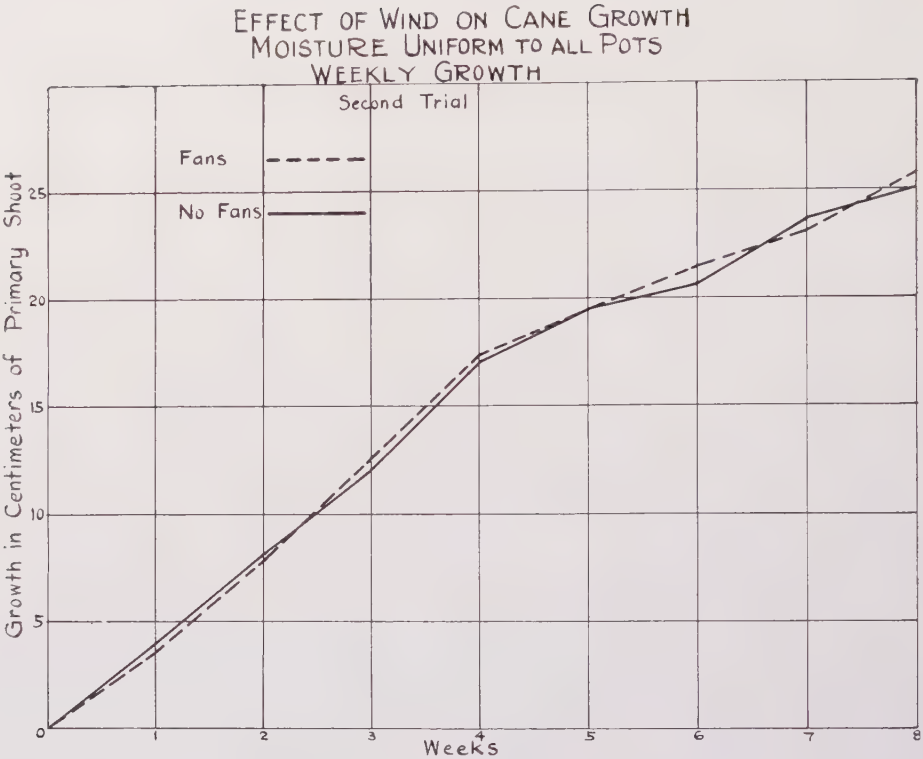


Fig. 3

soil near the stalks and may have hastened the emergence of the new shoots. Also, the constant shaking caused irritation, which may have stimulated stooling. (See Figs. 1, 2, 3.)

Uniform Irrigation Series

In this test uniform irrigation was applied to all pots, the aim being to provide the "no fan" pots with an optimum moisture content.

The test was conducted in two series of three pots for each treatment. Large galvanized iron pots were used for the test.

The results are summarized as follows:

TOTAL GROWTH OF PRIMARY SHOOT

	1st trial	2nd trial	Average per cent loss due to fans
Fans	8.3 inches	11.2 inches	20
No Fans	12.0 inches	12.3 inches	

GREEN WEIGHT OF ABOVE GROUND PORTION

	1st trial	2nd trial	Per cent loss in weight
Fans	8.9 ounces	6.5 ounces	35
No Fans	14.8 ounces	8.9 ounces	

From these tests we see that even moderate winds producing no appreciable physical damage to the leaves produce very substantial losses in weight. When the evaporation factor is eliminated by keeping an optimum moisture content in all pots, the indicated loss in this test is 14 per cent, but when the evaporation factor is added the loss in weight becomes 35 per cent, showing that for dry conditions winds become very important factors in checking the growth of sugar cane. (See Figs. 4, 5, 6, 7, 8.)

Fig. 4. Fans were placed in front of these plants in the hothouse and allowed to run continuously for seven weeks. Compare the shoot growth with Figs. 2 and 3. Irrigation uniform to all pots.

Fig. 5. These plants were allowed to grow in the hothouse with no wind blowing on them. The shoot growth is better than in the case of Fig. 1, but not as good as in Fig. 3. Irrigation uniform to all pots.

Fig. 6. These three plants were allowed to grow in the open under ordinary conditions. Although the primary stalks are not as tall as in Figs. 1 and 2, more shoots have developed.

Fig. 7. The effect of wind on cane growth at a constant moisture of 25 per cent on the dry basis. These plants were kept in the hothouse for 56 days and during this period electric fans were placed in front of the plants and were allowed to run continually.

Fig. 8. The effect of no wind on cane growth at a constant moisture of 25 per cent on the dry basis. The plants in this picture were kept in the hothouse for a period of 56 days, no wind being allowed to reach them.

Replaceable Bases in the Soils of Central Maui

By F. E. Hance and G. R. Stewart

Introduction

In recent years there has been an increasing study of the base replacement occurring in soils that are treated with saline waters. The phenomenon of base replacement was first investigated comprehensively in 1850, by J. T. Way (9), in England. This work was undertaken in order to find the nature of the fixation which takes place when salts of ammonium, potassium or phosphoric acid are added to the soil. Way was able to show that this fixation was an actual chemical reaction between the clay of the soil and the fertilizing salt. In this reaction the base of the fertilizing material was absorbed by the clay and an equivalent amount of calcium was displaced from the soil colloid.

Later Hissink (4), in Holland, studied the effect that ocean water had upon the soil of tidal flats. When this land was reclaimed and brought under cultivation certain areas were found to be infertile. Hissink showed that this infertility was associated with the replacement of the calcium in the soil colloid by the sodium of the sea water. His work showed clearly that base replacement was a general phenomenon which involved the same type of interaction that Way had observed in the case of fertilizing salts.

Gedroiz (2), working in Russia, has investigated the base exchange which has taken place in the alkali soils of the Russian steppes. He has shown that base replacement always occurs in the clay or colloidal portion of the soil. Gedroiz demonstrated the effect of toxic concentrations of sodium upon soils of normal productivity and good physical texture. The result of such applications was to cause a gummy, deflocculated condition in the soil and this, he showed, was caused by the replacement of calcium by sodium.

Kelly (5), in California, has found the underlying cause of soil impermeability to be an excess of replaceable sodium. He states: "It now seems certain that some of the most difficult phases of the alkali problem of semi-arid regions are closely related to and indeed caused by the substitution of sodium for one or more of the bases normally present in replaceable form. There are two especially important effects produced by the substitution of sodium for the divalent bases, namely: (1) the granular structure of the clay materials becomes broken down with the resulting development of extreme impermeability; (2) sodium carbonate is formed as a result of hydrolysis."

The injurious effect of soluble salts in irrigation water has been observed in many semi-arid countries. Here in Hawaii, cane fields are, in some cases, necessarily irrigated with slightly saline artesian waters. This has occasionally resulted in some injury to cane crops, but so far we have not had to face an acute alkali problem. Work previously carried out by one of us (G. R. Stewart) clearly

indicates that this comparative freedom from injury is due to the appreciable calcium content of the pump waters.

It has been found on the mainland by Kelley and Thomas (6), and later by McGeorge (7), that the reclamation of saline soils could not be accomplished, solely, through the substitution of a good water for one containing soluble salts. The water of higher purity leached out the soluble sodium salts, but left the soil in a practically impermeable state. Such a condition caused the failure of the attempted reclamation. Upon planting crops in such deflocculated land it was found to be in a worse state for crop growth than it was when the soluble salts were present. This infertile condition, developed in the work carried on in California and Arizona, was found to be due to excessive amounts of replaceable sodium in the soil colloids. For those of our readers who care to follow a semi-technical discussion of the theory of base replacement we append the following summary:

The Theory and Mechanism of Base Replacement

A base may be defined in chemistry as the oxide or hydroxide of the alkali metals lithium, sodium, potassium, etc. The alkaline earth metals, magnesium, calcium, stroutium, etc., are likewise basic. The term also includes the hydroxide of ammonium and the hydrides of other non-metals such as pyridine, phosphorus, etc.

Following the common convention we will use the term in this discussion to include only that portion of a compound or salt which imparts the alkaline characteristic to a true base. For example, the salt potassium chloride, which in itself is not alkaline in reaction, would be called a basic compound because the alkali metal potassium forms a part of its molecule.

A replaceable base may include the alkaline constituent of any of the salts of the basic elements or radicals mentioned above. Chlorides, sulphates, nitrates, carbonates, silicates, phosphates of potassium, sodium, ammonium, calcium and magnesium are the compounds which function in the more common replaceable base reactions. Under certain conditions aluminum, iron, manganese and hydrogen are also apparently found in the replaceable form.

In order that a base may become replaceable it must become detached from the parent salt and assume an unique position in the soil colloid. The only "change of state" in a compound which would favor the detaching phenomenon just mentioned without chemical reaction is the process of ionization. When the salt potassium chloride ionizes in aqueous solution, the bonds which hold its two component elements, K and Cl, in electrical neutrality, cease to maintain that union. As a result the potassium atom floats off as a separate entity, the potassium ion. It carries one extra positive charge of electricity. This entity or unit, in common with all the other bases, constitutes the elemental factor in base replacement. We have stated that the ion, potassium, carries a positive charge of electricity. The small particles of the soil colloid are charged with negative electricity. When brought in contact these oppositely charged particles unite by mutual attraction, the base

assuming a position on the surface of the infinitely small and united mass. The base, potassium, has now become a part of the colloidal soil complex. The attraction which holds it is peculiar in two respects: First, leaching with pure water in unlimited volume would not dislodge it; second, contact with a solution containing any other base would immediately result in a replacement in which the potassium would exchange places with the prevailing base of the solution. The process is reversible, the limiting conditions being a matter of concentration or dominance of any one base or group of bases, in the soil solution. When the exchange takes place the base leaving the soil colloid assumes the position of the exchanging element in the soil solution. To illustrate: Assume that the base calcium was in combination with the soil colloid as "replaceable calcium." Now, if a solution of sodium chloride passes down through the soil, calcium will be removed from the soil colloid and sodium will replace it. A solution of calcium and not sodium chloride now continues downward. The illustration, of course, is an extreme case.

The theory underlying the exchange process is stated by Hissink (3) as follows: "The exchangeable bases are located on the surface of the soil particles; in other words, they occur in the adsorbed condition. The cause of this adsorption is to be sought in the chemical attraction between the bases and the soil acids (clay and humus acids). When the soil is treated with water, a soil suspension is formed. A part of the surface molecules then become ionized, forming around the surface of the adsorbing clay and humus particles an electrical double layer. In the inner part of this double layer are found the anions of soil acids, in the outer part the kations H^+, Mg^{++}, Ca^{++}, K^+, Na^+, etc."

Gedroiz (2), Kelley (5) and Burgess (1) have shown that the physical and chemical properties and reactions of a soil are largely dependent upon the relationships existing between the various replaceable bases which may be present. These investigators have admirably presented the subject from the theoretical standpoint. They have, in addition, cited data from numerous practical applications of the principles involved and have made valuable recommendations as to corrective measures to employ in returning a salt-damaged soil to fertility.

Experimental

The present study is devoted to the attempt to ascertain if an unfavorable interchange of bases was associated with the failure of H 109 cane in certain limited areas in Central Maui. These poor spots were located in the fields of the Hawaiian Commercial and Sugar Company at Puunene, and ranged in size from 1/20 to ½ acre. The total area affected in the entire plantation was not large, as it would probably not exceed 35 or 40 acres. The poor cane, however, was notably stunted and in some cases died out completely. The immediate failure of the cane was found by Muir (8) to be associated with heavy infestations of several varieties of nematodes which attacked the roots. Following these nematode attacks the roots of the poor cane broke down and largely rotted away.

The areas of poor cane were clearly marked off from the surrounding good stools, and suggested the possibility of some soil difference existing in these locali-

ties. An unfavorable soil condition might conceivably, either affect the vitality of the cane so that the stools would be unable to resist nematode attacks, or might be conducive to an unusual development of nematodes in the poor areas.

Practically all the poor cane was located in fields which had been irrigated with pump water containing appreciable amounts of soluble salts. Samples of soils from many of the poor spots and from adjoining good portions of the fields were collected by one of us (G. R. Stewart), and by Hansson, of this Experiment Station. Analyses of the displaced soil solutions and of the soluble salts did not show any consistent differences between the good and poor soils.

The association of plant failure with unfavorable basic ratios in a diversity of soils and crops, throughout continental United States and Europe, suggested the desirability of applying a similar study to the infertile areas of Hawaiian soils. This decision was reached by the head of the department of chemistry, after careful consideration of the factors which, in his experience, indicated that base replacement was possibly one of several causes contributory to root failure in the segregated poor areas previously described.

It then remained to determine whether the replaceable bases present in the good and poor soils were sufficiently different to account for the infertility of the poor spots.

The replaceable bases were accordingly determined in both the surface soil and subsoil in a series of the good and poor portions of the fields of Hawaiian Commercial and Sugar Company. The determinations were carried out on the subsoil as well as the surface soil in order to obtain some information as to the depth to which base replacement would take place. We anticipated that if an unfavorable replacement of bases had occurred in these soils, it would consist in the partial or entire substitution of calcium by sodium. The data on a series of the typically good and poor soils from Puunene are given in Table I. The figures for replaceable bases are presented in three different forms: first, as the actual per cent of bases present in the soil; second, as the relative percentage of each of the four principal bases; third, as the ratio of replaceable calcium to magnesium. A careful study of our results showed, contrary to our expectation, that the content of replaceable sodium was not exceptionally high. In several cases, in fact, the replaceable sodium was present in larger amounts in the good than in the poor soils. We found, however, that one constant relationship did appear to exist between the good and poor areas. In all cases the good soils had a lower content of replaceable magnesium than was found in the adjoining poor soil. These unfavorable ratios of calcium to magnesium were more evident in the surface soil of the poor areas than in the subsoil.

The poor area sampled in Field 18, Hawaiian Commercial and Sugar Company, shows an extreme instance of a high content of replaceable magnesium. It will be seen that the ratio of calcium to magnesium in the poor soil was 0.95 calcium to 1.00 magnesium. In the soil where good cane was growing, a few feet distant, the ratio was 1.75 calcium to 1 magnesium.

TABLE I

Plantation	Field No.	Condition of Cane	Surface or subsoil	Cane variety	Per cent bases in soil				Relative per cent of bases				Ratio Ca to 1 Mg
					Ca	Mg	K	Na	Ca	Mg	K	Na	
H. C. & S. Co.	18 Co. 4	Poor—roots almost dead	Surface	H 109	.13	.14	.09	.05	32	34	22	12	0.95
H. C. & S. Co.	18 Co. 4	Poor—roots almost dead	Subsoil	H 109	.19	.16	.13	.08	33	29	22	16	1.14
H. C. & S. Co.	18 Co. 4	Good cane	Surface	H 109	.16	.09	.10	.08	37	21	23	19	1.75
H. C. & S. Co.	18 Co. 4	Good cane	Subsoil	H 109	.16	.10	.13	.06	36	22	29	13	1.64
H. C. & S. Co.	E	Poor cane	Surface	H 109	.18	.16	.06	.08	38	33	13	16	1.15
H. C. & S. Co.	E	Poor cane	Subsoil	H 109	.17	.15	.06	.08	38	32	13	17	1.20
H. C. & S. Co.	E	Good cane	Surface	H 109	.19	.11	.07	.05	45	26	17	12	1.73
H. C. & S. Co.	E	Good cane	Subsoil	H 109	.18	.12	.06	.07	42	28	14	16	1.50
H. C. & S. Co.	7 Co. 2	Partly sick cane	Surface	H 109	.41	.05	.08	.04	80	11	2	7	7.30
H. C. & S. Co.	7 Co. 2	Good cane	Surface	H 109	.25	.026	.08	.03	79	8	2.5	10	9.90
H. C. & S. Co.	18 Co. 1	Poor cane	Surface	H 109	.22	.13	.12	.07	40	25	22	13	1.60
H. C. & S. Co.	18 Co. 1	Good cane	Surface	H 109	.24	.10	.10	.08	46	19	19	15	2.40
H. C. & S. Co.	2 Co. 43	Poor cane	Surface	H 109	.26	.12	.07	.06	51	23	14	12	2.20
H. C. & S. Co.	2 Co. 43	Good cane	Surface	H 109	.31	.10	.09	.07	55	17	16	12	3.30

In order to confirm these unusual results it was decided to determine the replaceable bases in a series of other soils from Central Maui, in which good and poor Lahaina cane was growing. The following soils were used:

1. A virgin soil from Field 96, Maui Agricultural Company. No cane was growing on this land.

2. Soil from a plant field of Lahaina cane, where excellent cane was growing. Field 96, Maui Agricultural Company.

3. Soil from a first ratoon field of Lahaina cane, where there was some evidence of failure. Field 95, Maui Agricultural Company.

4. Soil from an area of abandoned Lahaina cane. Field A, Company 27, Hawaiian Commercial and Sugar Company.

The determinations of replaceable bases on these soils are given in Table II. It will be seen that in the virgin soil the ratio of replaceable calcium to magnesium is 6.7 to 1. In the soil of the plant fields of Lahaina the ratio is 5.3 to 1. In the first ratoon field the ratio of calcium to magnesium was 3.4 to 1, while in Field A, where Lahaina cane was growing very poorly the ratio was 1.05 to 1. These data appear to confirm the previous observation regarding the unfavorable influence of a high content of replaceable magnesium. There are several points, however, which should be considered before such a conclusion is accepted. The three soils from the Maui Agricultural Company fields have not been treated with saline waters. The virgin soil has not received any irrigation and the other two soils have been irrigated with mountain water. We have no present evidence that Lahaina cane absorbs an exceptional quantity of calcium, so the higher ratio of replaceable calcium in the better soils may possibly be a matter of variation in the composition of the original soil. The association of a high content of replaceable magnesium with a poor condition of the cane is, however, extremely consistent.

In order to obtain more definite experimental evidence of the toxic effect of a high content of replaceable magnesium we have under way the following series of soil treatments. The first series consists of seven pots, each holding 61 pounds of soil, from the Makiki plots of this Station. This soil in its original state is a fertile soil with a high ratio of replaceable calcium to replaceable magnesium. Four pots, to be kept as controls, were leached, 15 gallons of distilled water per pot. The three remaining pots were first leached with 5 gallons of 1/10 normal solution of magnesium sulphate. This treatment was followed by leaching with 10 gallons of distilled water. The net effect of this treatment was to secure, in three pots, a soil with a high content of replaceable magnesium, but free from soluble magnesium sulphate. The four controls had the original high ratio of replaceable calcium to replaceable magnesium. Each pot of the entire series was subjected to the same leaching of the soluble soil nutrients by the treatment it had received.

The pots were each planted on February 3, 1927, with uniform three-eye seed pieces of H 109 cane, from which two eyes were removed. The effect of the replaceable magnesium has been apparent from the first appearance of the young shoots. The cane in the magnesium treated pots has been stunted and spindly. No secondary or tertiary shoots have appeared during the three months' growth, while the cane growing in the control pots sent out both secondary and tertiary

TABLE II

Plantation	Field No.	Condition of Cane	Surface or subsoil	Cane variety	Per cent bases in soil				Relative per cent of bases				Ratio Ca to 1 Mg
					Ca	Mg	K	Na	Ca	Mg	K	Na	
M. A. Co	96 Virgin soil		Surface	None	.33	.05	.08	.02	67	10	18	5	6.7
M. A. Co	96 Plant cane	Very good	Surface	Lahaina	.33	.06	.09	.03	64	12	18	5	5.3
M. A. Co	95 First ratoon	Shows failure	Surface	Lahaina	.26	.07	.08	.04	58	17	18	7	3.4
H. C. & S. Co	A Co. 27	Very poor cane	Surface	Lahaina	.17	.16	.07	.06	37	35	15	13	1.05
H. C. & S. Co	A Co. 27	Very poor cane	Surface	Lahaina	.16	.14	.07	.06	37	32	17	14	1.15

shoots at an early date. The soil in the magnesium treated pots has undergone a notable change in texture and has become rubbery and impermeable. After heavy rains, puddles of water persist above the surface of the treated soils until it is removed by evaporation. Both rain water and irrigation have always passed rapidly through the controls.

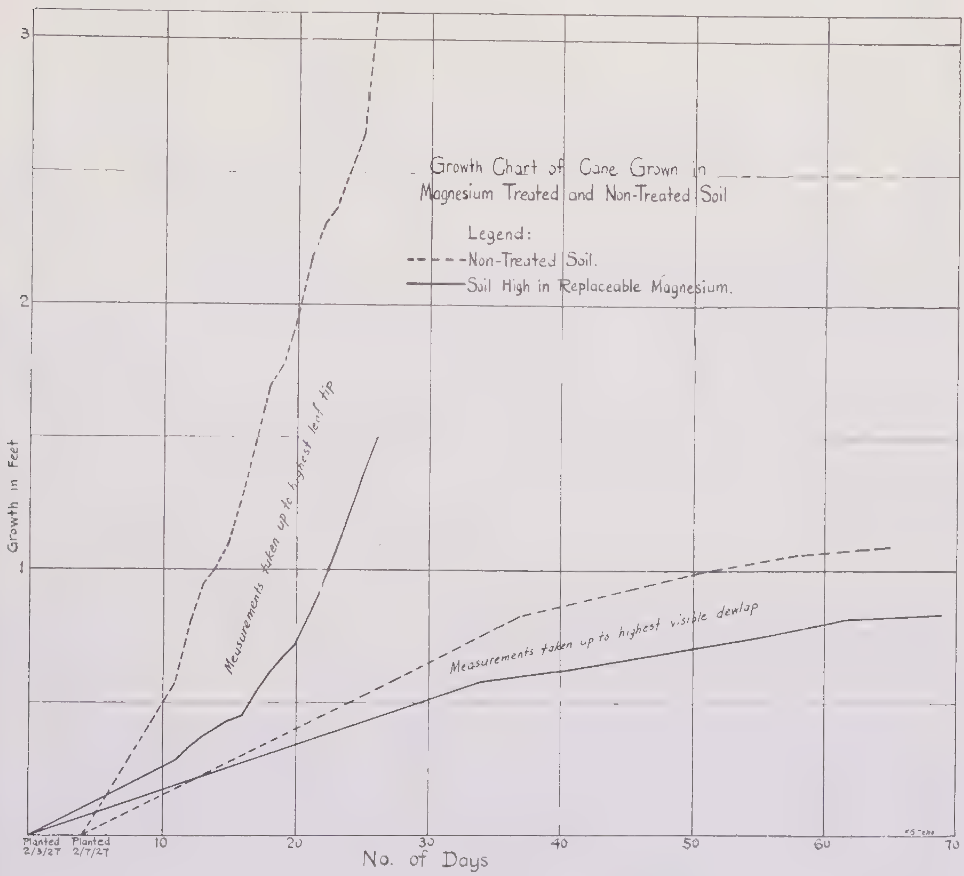


Fig. 1

Growth measurements have been made on the cane grown in the treated and untreated pots. The growth of the best control as compared to the best of the magnesium treated plants is shown in Fig. 1. Photographs of the growth made in typical pots at monthly intervals are shown in Figs. 2 and 3.

On May 3, the entire plants were removed from 1, the untreated control, and from 2, the magnesium treated pot from which growth measurements had been taken during the three months' interval. Fig. 4 is a photograph of these two specimens which was taken soon after removal from their respective pots. The roots of the cane grown in the environment of high replaceable magnesium are badly stunted and deficient in secondary roots. The effect of the cutting off of atmospheric air by the impermeable soil is shown by the abnormal bleaching and whitening of the entire root system. The failure of secondary or tertiary shoots

Fig. 2. H 109 cane planted February 3, 1927. Pots 1, 3 and 5 are magnesium treated; pots 2 and 4 are controls. Photographed March 7, 1927.

Fig. 3. H 109 cane, showing the second month's effect of growth in untreated and in magnesium treated soils. The end pots are magnesium treated. The water, which may be observed in the illustration, remained after a rain occurring three days previously. The center pots are controls. Photographed April 4, 1927.

Fig. 4. Showing the effect of three months growth of H 109 cane in untreated Makiki soil (left), and in magnesium treated Makiki soil (right).

to appear above ground may also be observed in the illustration. The plant grown in the untreated soil is normal in all respects.

The condition of the cane grown in other magnesium treated soils of this experiment was found to be more abnormal than the specimen photographed. This naturally follows since only the best growths of both controls and magnesium treated soils were selected for measurement and comparison. The toxic effect of the magnesium treatment, upon cane grown in this soil, is clearly indicated.

We have treated the soil in the magnesium pots with calcium nitrate in an attempt to restore the soil to its original condition. The attempt at reclamation consisted of passing 5 gallons of ⅝ normal calcium nitrate solution through each pot of magnesium treated soil. This operation should bring about replacement of the magnesium by the calcium of the calcium nitrate solution. To remove all soluble calcium and magnesium nitrates each pot was subjected to a leaching with 10 gallons of distilled water. The pots are now planted to H 109 cane to test the efficiency of the reclamation.

We have another series of experiments under way in which we are using both good and poor soils from the fields of the Hawaiian Commercial and Sugar Company. In this series we have treated some of the good soils with soluble salts of magnesium, in order to study the harmful effect of this base, and have also treated the poor soils to try and remove the replaceable magnesium. This series was started at a later date (March 29) than the first experiment.

The preliminary indications are that the good soils from Puunene are not as readily flocculated as the soil from the Makiki plots. The impermeability of the soil became evident not immediately, as in the case of the Makiki experiment, but only after the seed pieces had been planted and one heavy irrigation had been made. We attribute this to the high granular condition of the soil and its failure to pack sufficiently after planting to enable the newly imparted and undesirable physical condition to become manifest. This conclusion is justified by the four-inch settling which has since occurred and the appearance of the rubbery condition which characterized the magnesium treated Makiki soil. The cane growing in this soil is suffering from the magnesium treatment the soil received, the damage being very pronounced at this writing (May 10).

There is every indication that the treatment of the poor soil with calcium nitrate solution has notably improved its condition and promises to be a feasible method of reclamation.

Discussion

The above results appear to us to indicate that, in the soils of Central Maui, which we have investigated, the occurrence of a high content of replaceable magnesium in certain poor areas is related to the partial failure of H 109 cane in these spots. The present report is to be regarded as a progress report on this investigation. Hence we do not wish as yet to attempt to evaluate the various unfavorable influences which have contributed to the final failure and destruction of the cane roots. Nematode injury has been closely associated with the actual root destruction. Fungi or bacteria would unquestionably follow the nematodes and

would play some part in the breakdown of the roots. Cooperative experiments with the other departments of the Station will be necessary before we can attempt an accurate analysis of the various factors affecting cane growth in these poor spots. As a preliminary we plan certain remedial chemical treatments which should furnish excellent locations for the study of the effect of the biological factors influencing root development.

These remedial treatments will be as follows:

(1) The replacement of magnesium and sodium in the soil of the poor areas by saturating the irrigation water with calcium sulphate. We believe this may be done by installing a baffled box in the supply ditch with a series of pockets which should be partly filled with powdered gypsum. Such a treatment would not preclude the use of pump water, if that has been the usual practice. Care must be observed, however, to see that the supply of gypsum is replenished so that there may always be an adequate excess of calcium in solution. This base must be present in decidedly larger amounts than all other bases present in the water. If this method gives a saturated solution of gypsum, the water entering the field will contain one pound of calcium sulphate in every 50 gallons of water, which should cause calcium replacement in the worst soils we have thus far examined.

(2) In severe cases of magnesium or sodium injury a treatment of calcium nitrate should be worked into the surface soil before the water saturated with calcium sulphate is applied. This will insure a sufficient excess of soluble calcium over other bases at the beginning of the attempted reclamation. A preliminary determination of the replaceable bases present in the soil will indicate the amount of calcium salts which it will be necessary to apply. Even should the amounts of calcium nitrate be in excess of the immediate nitrogen requirement of the cane crop, previous work of one of us (G. R. Stewart) has shown the high tolerance of H 109 cane for heavy nitrate applications.

(3) It is generally desirable to apply some form of organic material after soil treatments which involve leaching through excessive irrigation. The organic residues will increase the soil colloids and assist in retaining soil moisture in the root zone. Mud press is particularly desirable as a source of organic matter because in addition it supplies an appreciable application of lime. Where it is available and can be applied to fallow land, molasses can be used both as a source of organic matter and potash. Sulphur and stable manure will also constitute a valuable treatment for many soils which are naturally alkaline and contain an excess of calcium carbonate.

Summary

(1) Chemical examination of the soils from a series of infertile areas in Central Maui has shown that these soils contain a higher content of replaceable magnesium than is found in adjoining fertile land.

(2) Pot treatments of good and poor soils indicate that the presence of this excess of replaceable magnesium in the poor soils may be associated with the partial growth failure which has occurred.

(3) The relationship of this replaceable magnesium to biological conditions in the soil remains to be determined.

(4) Possible remedial treatments for an excess of replaceable magnesium have been indicated by our work and will shortly be tried in the field.

Literature Cited

1. Burgess, P. S., and Breazeale, J. F., 1926. Methods for determining the replaceable base of soils, etc. Univ. Arizona, Col. of Agr. Exp. Sta. Tech. Bul. No. 9.

2. Gedroiz, K., 1916. The absorbing capacity of the soils and the zeolitic bases. Zhur. Opit. Agron. 17, 472,526.

3. Hissink, D. J. Base exchange in soils. A general discussion held by the Faraday Society, 1924, p. 553.

4. Hissink, D. J. Beitrage zur Kenntnis der. Adsorptionvorgänge im Boden, 1922, 12, 81-172.

5. Kelley, W. P., and Brown, S. M., 1924. Replaceable bases in soils. Cal. Agr. Exp. Sta. Tech. Paper No. 15, p. 2.

6. Kelley, W. P., and Thomas, E. E., 1923. The removal of sodium carbonate from soils. Cal. Agr. Exp. Sta. Tech. Paper No. 1.

7. McGeorge, W. T., Breazeale, J. F., and Burgess, P. S., 1926. Aluminum hydroxide in alkaline soils and its effect upon permeability. Univ. of Ariz. Col. of Agr. Exp. Sta. Tech. Bul. No. 12.

8. Muir, F. Monthly Report, Exp. Sta. H. S. P. A., January, 1926.

9. Way, T. J. On the power of soils to absorb manure, 1852. Jour. Roy. Agr. Soc. 13, 123-143.

A Generic List of the Spear-Bearing Nematodes With a Revised Dichotomous Table

By F. Muir, Gertrude Henderson and R. H. Van Zwaluwenburg

Since the generic table of spear-bearing nematodes was published in *The Hawaiian Planters' Record,* October, 1926, further specimens and literature have come to hand enabling us to enlarge and revise that work. The table presented herewith is mainly based upon literature and must not be considered as final, but it is an improvement upon the former. It is published as a help towards identifying the spear-bearing nematodes found in Hawaii. In cases of uncertainty the same genus has been placed in two divisions.

Of the thirty-five genera considered in the list most of them belong to the true hollow spear-bearers, Dorylaimidae and Tylenchidae of many authors, while a few would come into the Diphtherophoridae. They roughly come under Tylen-

chidae of Micoletzky. Forms such as *Campydora, Onchium* and *Onchulella* have not been included as they evidently have a solid tooth and not a hollow spear.

Baylis and Daubney in their useful "Synopsis of the Families and Genera of Nematoda" have accepted *Vibrio tritici* as the type of *Anguillulina* Gervais and van Beneden. This would then supersede *Tylenchus,* both as a generic and family name. Even if this be correct we consider the change is undesirable as *Tylenchus* is a large genus having a large literature and in recent years has become known in economic work. It is better to treat this case as one for *nomina conservanda.*

A great deal of work has yet to be done before this matter of classification and synonymy of these animals can be satisfactorily settled. At present there are two main classifications, one taking the structure of the spear as of chief importance, the other taking the structure of the oesophagus. We have used the former. The question of synonymy in many cases is a personal affair, as the information at present available is not sufficient to judge by. The same can be said as to what should be considered as a genus or subgenus. In the dichotomous table and list those names considered as generic are given under numbers, those considered as subgeneric under letters. The genera at present known to occur in Hawaii are printed in heavy type.

Tylencholaimus aequalis Cobb does not appear to be congeneric with *Tylencholaimus mirabilis* de Man, so it has been separated in the table, but a new name has not been given to it.

List of Genera and Subgenera of Spear-Bearing Nematodes

1. **Actinolaimus** Cobb 1913, Jour. Wash. Ac. Sci. 3, p. 439. Orthotype *radiatus* Cobb.
2. **Aphelenchoides** Fischer 1894, Ber. d. phys. Lab. d. landw. Inst. Halle, Dresden, III (1), p. 1, Haplotype *kuhnii* Fischer.
   This is not mentioned by Micoletzky in his Die freilebenden Erd-Nematoden. The literature is not available so it cannot be placed in the table.
3. **Aphelenchulus** Cobb 1920, One Hundred New Nemas (Waverly Press), p. 301. Haplotype *mollis* Cobb.
4. **Aphelenchus** Bastian 1865, Tr. Linn. Soc. Lond, XXV, p. 93, 121. Logotype *avenae* Bastian.

(a) *Chitinoaphelenchus* Micoletzky 1922. Arch. f. Naturg. 87, Abt. A, H. 8, p. 119, H 9, p. 586. Type *ormerodis* Ritzema—Bos.

(b) *Paraphelenchus* Micoletzky 1922, t. c. p. 603. Type *pseudoparietinus* Mic. The females of this genus are difficult to separate from *Tylenchus.*

5. **Archionchus** Cobb 1913, Jr. Wash. Ac. Sci. (3), p. 438. Haplotype *perplexans* Cobb.
6. **Atylenchus** Cobb 1913, Jr. Wash. Ac. Sci. (3), p. 437. Haplotype *decalineatus* Cobb.
7. **Brachynema** Cobb 1893. Nematode worms found attacking sugar cane. New South Wales Dept. Agric., p. 34. Haplotype *obtusa* Cobb.
   Name preoccupied by Brachynema Fieb, 1861, Hemiptera. Unable to place this genus; Baylis and Daubney suggest it may be near *Tylencholaimus.*

8. **Deontolaimus** Man 1880. Tijdschr. Nederl. dierk. Vereen. Leiden 3. Haplotype *papillatus* Man.
9. **Diphtherophora** Man 1880. t. c. p. 62. Haplotype *communis* Man.
Syn. *Chaolaimus* Cobb 1893. Nematode worms found attacking sugar cane. N. S. W. Agr. Dept., p. 44. Haplotype *pellucidus* Cobb.
10. **Dolichodorus** Cobb 1914, Tr. Am. Micr. Soc. 33, p. 94, Haplotype *heterocephalus* Cobb.
11. **Dorylaimus** Dujardin 1845, Hist. Nat. des helm. ou vers intest., Paris, p. 230. Logotype probably *stagnalis* Dujardin 1845.
Syn. *Antholaimus* Cobb 1913, Jr. Wash. Ac. Sci., p. 440. Haplotype *truncatus* Cobb.
Syn. *Nygolaimus* Cobb 1913, Jr. Wash. Ac. Sci. (3), p. 441. Haplotype *pachydermatus* Cobb.
(a) *Axonchium* Cobb 1920, One Hundred New Nemas (Waverly Press), p. 305. Haplotype *amplicolle* Cobb.
(b) *Discolaimus* Cobb 1913. Jr. Wash. Ac. Sci., p. 439. Haplotype *texanus* Cobb.
(c) *Dorylaimellus* Cobb 1913, Jr. Wash. Ac. Sci. 3, p. 440. Haplotype *virginianus* Cobb.
(d) *Doryllium* Cobb 1920. One hundred New Nemas (Waverly Press), p. 303. Haplotype *uniforme* Cobb.
(e) *Longidorus* Micol. 1922. Arch. f. Naturg. 87, Abt. A, H. 9, pp. 442, 458, 527. Type elongatus Man, 1876.
12. **Ecphyadophora** Man 1921, Capit. Zool. I, p. 35. Haplotype *tenuissima* Man. This genus cannot be placed on account of incomplete description.
13. **Eutylenchus** Cobb 1913, Jr. Wash. Ac. Sci., p. 437. Haplotype *setiferus* Cobb.
14. **Heterodera** Schmidt 1871, Zeitsch. d. ver. f. Ruben-Indust. in Zollverein, XXI, pp. 1-19. Haplotype *schachtii* Schmidt 1871.
Syns. *Caconema* Cobb 1924, Jour. Parasit. XI, p. 118. Haplotype *radicicola* Greef 1872.
Heterobolbus Railliet 1896. Rec. Med. Vet. Paris, LXXIII, p. 161. New name for *Heterodera*.
Meloidogyne Goldi 1889, Zool. Jahrb. Jena. IV, p. 262. Orthotype *exigua* Goldi.
If *radicicola* and *schachtii* are not congeneric and if *exigua* is congeneric with *radicicola*, then *Meloidogyne* Goldi must take precedence over *Caconema*.
15. **Hexatylus** Goodey, 1926. Jour. Helmin. IV, p. 27. Haplotype *viviparus* Goodey.
16. **Hoplolaimus** Daday 1905, Zoologica, Stuttgart XVIII, p. 62. Haplotype *tylenchiformis* Daday.
Syn. *Criconema* Hofmanner and Menzel 1914, Zool. Anz. XLIV, p. 88. Logotype probably *Eubostrichus guernei* Cretes, 1889.
Syn. *Iota* Cobb 1913, Jr. Wash. Ac. Sci., p. 437. Orthotype *squamosa* Cobb 1913.

Syn. *Ogma* Southern 1914, Pro. Roy. Irish Ac. Dublin, XXXI, (3), p. 66. Haplotype *murrayi* Southern.

If *Iota* has "retrorse scales or bristles" then it is distinct from *Hoplolaimus*, but if it only has reticulations then it is probably the same, as in Hawaiian specimens the rings often break up and form reticulations on the lateral surfaces.

17. **Iotonchium** Cobb 1920, One Hundred New Nemas (Waverly Press), p. 302. Haplotype *Tylenchus imperfectus* Butschli, 1876.
18. **Isonchus** Cobb 1913, Jr. Wash. Ac. Sci. 3, p. 439. Orthotype *radicicolus* Cobb.
19. **Myenchus** Schuberg and Schroeder 1904, Verh. d. Naturh.—med. Ver. zu Heidelb. n. F. VII, p. 629-632. Haplotype *bothryophorus* Schuberg and Schroeder. The position of this parasitic genus is uncertain.
20. **Myoryctes** Eberth 1863. Ztschr. f. wissensch. Zool., Leipzig, XII, p. 530. Haplotype *weismanni* Eberth. The position of this parasitic genus is doubtful.
21. **Nemonchus** Cobb 1913, Jr. Wash. Ac. Sci. 3, p. 438. Haplotype *galeatus* Cobb.
22. **Paratylenchus** Micoletzky 1922, Arch. f. Naturg. 87, Abt. A, H. 8, 9, pp. 119, 605. Haplotype *bukowinensis* Mic.
23. **Pharetrolaimus** Man 1921, Capit. Zool., I, p. 42. Haplotype *sagittifer* Man. The oesophagus of the genus is not described. It may come next to *Xiphinema* or *Aphelenchus*.
24. **Psilenchus** Man 1921, Capit. Zool, I, p. 36. Haplotype *hilarulus* Man.
25. **Trichodorus** Cobb 1913, Jr. Wash. Ac. Sci. 3, p. 441. Haplotype *obtusus* Cobb.

    Syn. *Leptonchus* Cobb 1920. One Hundred New Nemas (Waverly Press), p. 304. Haplotype *granulosus* Cobb.
26. **Triplonchium** Cobb 1920. One hundred New Nemas (Waverly Press), p. 300. Haplotype *cylindricum* Cobb.
27. **Tylencholaimellus** M. V. Cobb, 1915. Tr. Amer. Micr. Soc. XXXIV, p. 28. Haplotype *diplodorus* M. V. Cobb.
28. **Tylencholaimus** Man 1876. Tijd. d. Nederl. dierk. Vereen. Deel 2, p. 119. Logotype *mirabilis* Butsch. 1873.
29. **Tylencholaimus** Cobb not de Man, 1918. U. S. D. A. Tech. Circ. I. Estimating nema popul. soil. Haplotype *aequalis* Cobb.
30. **Tylenchorhynchus** Cobb 1913. Jr. Wash. Ac. Sci. 3, p. 438. Haplotype *cylindricus* Cobb.
31. **Tylenchulus** Cobb 1913. Jr. Wash. Ac. Sci. 3, p. 287. Orthotype *semipenetrans* Cobb.
32. **Tylenchus** Bastian 1865. Tr. Linn. Soc. Lond. 25 (2), p. 125. (On page 94 misspelled as *Tylelenchus*.) Logotype *davainii* Bast. 1865.

    Syn. *Parasitylenchus* Micoletzky 1922, Arch. f. Naturg. 87, Abt. A, H. 9, p. 545, footnote. Type *Tylenchus contortus typographi* Fuchs 1915.

(a) *Chitinotylenchus* Micoletzky 1922. Arch. f. Naturg. 87, Abt. A, H. 8, p. 119, H 9, pp. 546, 575. Type *paragracilis* Micoletzky.

33. **Tylolaimophorus** Man 1880, Tijd. d. Nederl. dierk. Vereen. Deel 5, p. 63, Orthotype *typicus* Man.

34. **Tylopharynx** Man 1876. Tijd. d. Nederl. dierk. Vereen. Deel 2, p. 116. Haplotype *striata* Man.

35. **Xiphinema** Cobb. 1913. Jr. Wash. Ac. Sci. 3, p. 436. Haplotype *americanum* Cobb.

Dichotomous Table of the Genera of Spear-Bearing Nematodes

1\. 48. Spear with base distinctly enlarged, consisting of either a single structure or of three or more structures more or less amalgamated.

2\. 9. Spear consisting of three pieces, either separate or fused together at their distal extremities (rather indefinite).

3\. 4. Spear consisting of three separate spines; kappchen (spear cap) present; oesophagus muscular, without bulb.................. *Diphtherophora.*

4\. 3. Spear consisting of three pieces fused together apically, base trifurcate or knobbed.

5\. 6. Base of spear with three distinct swellings; oesophagus sometimes with median bulb .... *Tylopharynx.*

6\. 5. Spear split at base; oseophagus without median bulb.

7\. 8. Spear with a kappchen (spear cap); amphids transversely oval....... .... *Tylolaimophorus.*

8\. 7. Spear without a kappchen (spear cap); amphid stirrup shape......... ....*Tylencholaimus aequalis* Cobb.

9\. 2. Spear consisting of one piece or of three pieces fused together from apex to base, base distinctly enlarged.

10\. 11. Cuticle with very distinct rings or reticulations, broken or complete; spear strong and generally long (1/6 to 1/9 of body length).......... ....**Hoplolaimus.**

11\. 10. Cuticle without distinct rings or reticulations.

12\. 13. Spear short, thick, apparently attached to the side of the wall of pharynx, apex slightly enlarged; base swollen and oblique..........*Archionchus.*

13\. 12. Spear free except at base, not enlarged at apex, base not oblique.

14\. 15. Spear massive, distinctly divided into two parts, the anterior half being chitinous, the basal half transparent, the base not very distinctly enlarged. Head with a strong chitinous framework.........*Nemonchus.*

15\. 14. Spear not so massive and not divided into two parts.

16\. 19. Oesophagus without a median bulb.

17\. 18. Base of spear produced into six lobes, spear short; oesophagus considerably swollen behind nerve ring.......................*Hexatylus.*

18\. 17. Base of spear produced into three lobes.

19\. 20. Spear trifurcate at base or basal half considerably larger than distal half............................*Tylencholaimus aequalis* Cobb.

20\. 19. Spear bulbous at base, the enlarged basal part being much less than half.

21. 22. Oesophagus very slender in middle, swollen anteriorly and posteriorly. Spear long and slender; kappchen (spear cap) present. .. **Paratylenchus.**
22. 21. Oesophagus not so distinctly slender in middle.
23. 26. Spear very short, in some almost vestigial.
24. 25. Oesophagus with an elongate posterior bulb; spear obliquely truncate anteriorly .... *Tylencholaimellus.*
25. 24. Oesophagus cylindroid or faintly cephaloboid; spear nearly vestigial, apex acute .... *Aphelenchulus.*
26. 23. Spear long or very long.
27. 28. Spear very long. Amphids small, obscure.......................... ....*Tylencholaimus* Man. **Xiphinema.**
28. 27. Spear much shorter; amphids large, oval, deep, often protruded (especially when fixed in Flemming's solution). . *Triplonchium, Deontolaimus.*
29. 16. Oesophagus with a median bulbous swelling.
30. 31. Spear with a kappchen (spear cap), or the anterior half of the pharynx heavily chitinized .... *Tylenchorhynchus.*
31. 30. Spear without a kappchen (spear cap), or the anterior half of pharynx not heavily chitinized.
32. 35. Anteriorly with four large, distinct bristles or setae; (bursa trapezoid).
33. 34. Cuticle prominently and logitudinally striate; male without bursa or very obscure .... *Atylenchus.*
34. 33. Cuticle not prominently and longitudinally striate; male with distinct bursa .... *Eutylenchus.*
35. 32. Anteriorly without setae or bristles.
36. 37. Excretory pore behind the middle of body; adult female greatly enlarged; median bulb not well developed................ *Tylenchulus.*
37. 36. Excretory pore before middle of body.
38. 39. Oesophagus behind bulb indistinct, appearing as if the intestine joined the bulb; glands separate from oesophagus on dorsal surface as "salivary glands"; males without bursa.. .... **Aphelenchus.**
a. b. Anterior end with a chitinous ornamentation...... *Chitinoaphelenchus.*
b. a. Anterior end without such ornamentation.
c. d. Oesophagus distinctly separated from the intestine..... *Paraphelenchus.*
d. c. Oesophagus not so distinctly separated from the intestine............. .... **Aphelenchus.**
39. 38. Oesophagus behind bulb distinct.
40. 41. Amphids large, oval, deep, often protruded (especially when fixed in Flemming's solution) .... *Triplonchium.*
41. 40. Amphids unknown or small, more obscure, not protruded.
42. 43. Males without bursa or only rudimentary; adult females greatly swollen and incapable of movement.................................. **Heterodera.**
43. 42. Males with bursa; adult females not greatly swollen, capable of movement.
44. 45. Bursa lobate; spear very long (1/3 to 1/5 length of oesophagus)........ .... *Dolichodorus.*

45. 44. Bursa plain; spear smaller.
46. 47. Spear moderate, ⅕ to ⅓ the length of oesophagus........ **Tylenchus.**
a. b. Head without a chitinous cap........................ **Tylenchus.**
b. a. Head with a chitinous cap..................... **Chitinotylenchus.**
47. 46. Spear minute length ¼ to ⅕ the width of head......... *Iotonchium.*
48. 1. Spear composed of a single hollow piece, slightly and gradually enlarged to base, base truncate, not swollen or enlarged or produced into prongs.
49. 52. Oesophagus with a distinct median bulb; excretory pore present.
50. 51. Male bursa supported by prominent ribs................. **Isonchus.**
51. 50. Male bursa without ribs............................ *Psilenchus.*
52. 49. Oesophagus without a distinct median bulb; excretory pore absent.
53. 54. Anterior portion of pharynx large, cup shape, supported by radiating chitinous ribs or other structures, sometimes beset with small teeth .... *Actinolaimus.*
54. 53. Anterior portion of pharynx small, without such armature.
55. 56. Spear very long, slender and flexible................. **Trichodorus.**
56. 55. Spear thick, not flexible, proportionally shorter........... **Dorylaimus.**
a. b. Spear long, needle-like............................ *Longidorus.*
b. a. Spear not so long and needle-like, more spine-like.
c. d. Spear gradually enlarging from middle to base............ *Doryllium.*
d. c. Spear without such enlargement at base.
e. f. Oesophagus considerably swollen anteriorly........... *Dorylaimellus.*
f. e. Oesophagus not swollen at the anterior end.
g. h. Lip region discoid, expanded, sucker-like.............. **Discolaimus.**
h. g. Lip region not expanded.
j. k. Oesophagus cylindrical or slightly enlarged posteriorly, distinctly divided into two portions by a constriction................ *Axonchium.*
k. j. Oesophagus distinctly larger posteriorly than anteriorly; without a constriction.. **Dorylaimus.**

The Three Common Species of Nematodes in Sugar Cane in Hawaii

The three species of nematodes which play the chief part in the nematode problem of sugar cane in Hawaii are: *Heterodera schachtii, Heterodera radicicola,* and *Tylenchus similis.*

The following characters are employed to distinguish the three species:

Heterodera schachtii:

Male: Head shows a distinct six lobed chitinous cap; spear comparatively large and stout; striations very distinct; bursa absent or only rudimentary; testes single.

Female: Head shows a distinct six lobed chitinous cap; spear large and stout; striations very distinct; vulva in the slender female is near the posterior end. The gravid female is greatly swollen and is flask-shaped.

Larvae: The larval forms possess the same characteristics as distinguish the females. Confusion often arises between the young forms of *Heterodera schachtii; Heterodera radicicola* and *Tylenchus similis.* The larvae of *Heterodera schachtii* may be distinguished from *Heterodera radicicola* by the six lobed chitinized head piece and by the fact that they are noticeably less slender than corresponding forms of *Heterodera radicicola.*

The situation of the developing gonads, when visible, will distinguish them from *Tylenchus similis.* In *Tylenchus similis* the gonads are much nearer the middle than in *Heterodera schachtii.*

Heterodera radicicola:

Male: Head without chitinous cap, but divided into three distinct regions, in end view a median subquadrate and two lateral oval regions; spear comparatively slender; striations less distinct; bursa absent or very rudimentary; testes paired.

Female: Head as in male; spear as in male; striations as in male; vulva near the posterior end in the slender female; gravid female is greatly swollen and is flask-shaped.

Larvae: The larval forms possess the same characteristics as the female. They may be distinguished from the larvae of *Heterodera schachtii* and *Tylenchus similis* by the head characters. They are more slender than the larvae of *Heterodera schachtii* and differ from *Tylenchus similis* in the situation of the gonads.

Tylenchus similis:

Male: Head rounded and plain, without chitinous cap and constricted off by a distinct suture very similar to some species of *Aphelenchus.* Spear weaker than in the female and sometimes rudimentary; striations distinct; bursa present; testes single.

Female: Head with a distinct six lobed chitinous cap; spear well developed; striations distinct; vulva near the middle; gravid females are never swollen.

Larvae: The larval forms possess the same characteristics as the female. The head shows a strongly chitinized cap. The gonads are often distinct and are situated near the middle.

In short, the two species of *Heterodera* may be distinguished by the different head characters.

Heterodera schachtii and *Tylenchus similis* are usually more difficult to separate. In the male, the presence or absence of the bursa and the marked differences of the heads distinguish them. In the females, the position of the vulva, and in the gravid stages the swollen condition of the female *Heterodera schachtii* form good characters for separation.

The Preservation of Cane After Cutting From the Stool

By F. E. Hance

In the crossing of various varieties of cane it frequently becomes desirable to remove from the stool a number of tasseled stalks from a distant location to be placed adjacent to other varieties during the period of pollination.

Success is dependent not only in maintaining vigor and turgidity in the detached stalks for the duration of the experiment, but in securing an uninterrupted development in the upper extremities of the plant.

U. K. Das, of the agricultural department at this Station, has found that immersion of the cut stalk in a .03 per cent solution of sulphurous acid will, in many cases, preserve the cane for periods as long as five weeks. Das experimented with many solutions of acids, salts and organic preservatives. He found that the sulphurous acid solution was the only medium which, in his experience, gave reasonably satisfactory results in maintaining the life of the detached cane. When a freshly cut stalk is placed in water, evidence of wilting will usually be observed in about fifteen to twenty hours. A brownish-red bacterial growth will then be found in small amounts on the cut end of the immersed stalk. The bacterial formation rapidly spreads over the entire cut surface, closing the vascular bundles and the cane quickly succumbs from lack of moisture. The presence of minute amounts of sulphurous acid inhibits this bacterial formation.

The studies of D. M. Weller, of the pathology department, seem to indicate that sulphurous acid may possibly have a detrimental effect on the vitality of the pollen.

It appeared desirable, then, to seek an immersion medium which would maintain vitality in the cut plant without imparting to it any appreciable soluble or volatile toxins.

Many experiments were conducted over a period of several months. The author was ably assisted in this work by F. G. Teho. We were unable to find any solutions which were entirely satisfactory for the preservation of the cut stalk by immersion of the butt.

We found, however, that an acid solution of sodium nitrite would preserve the cane over a period of several weeks. The nitric oxide, resulting from the decomposition of the nitrite salt, maintained a turgid, green condition, whereas the cane immersed in dilute sulphurous acid soon became yellow.

The table contains a memorandum of some of the solutions employed, with brief comments on the results obtained.

We felt that more satisfactory results could be developed if conditions were imposed which more nearly followed the natural functions of the growing cane.

Accordingly, our efforts were directed in devising a simple method of causing the cut stalk to send out roots into a nutrient medium. Our aim was to supply moisture and nutrient by means of feeding through an artificially developed root

system, rather than forcing moisture through the cut end of the stalk in an effort to balance evaporation from the leaves.

With the cut end immersed in a nitrite solution* a system of roots was grown about two feet from the lower end of a stalk in the following manner:

After cutting from the stool, a rubber boot (section of an old inner tube from an automobile tire) was slipped over the cut end. The lower end of the boot was then securely fastened to the stalk about a foot from its lower extremity. A liquid-tight joint between boot and stalk was obtained by binding the lower boot end with friction tape. The free end of the stalk below the boot was then immersed in the nitrite solution. The boot was then filled with tap water containing a few c.c.s of the dilute nutrient solution which is commonly employed in growth culture experiments. The upper end of the boot was closed so as to exclude light. In about three to four days roots began to appear at the nodes nearest the top of the boot. Instead of extending downward into the confined liquid the roots grew upward, the extremities terminating in free air. This tendency was reversed by bubbling a slow and continuous stream of oxygen through the solution in the boot. (Atmospheric air would have been employed instead of oxygen, but no method was available at the location of the experiments to permit its use.)

A photograph of one of the stalks is shown in Fig. 1. The roots illustrated are four days old, having first appeared after the fifth day of treatment. The boot is shown rolled down near the base of the stalk, the latter still immersed in nitrite solution.

Fig. 2 is an enlargement of the same root system shown in Fig. 1.

After about the fifteenth to the twentieth day of root growth, transpiration of moisture from the nitrite solution, through the cut end of the stalk, usually ceased entirely. The moisture requirements of the plant were then supplied through the roots from the solution in the boot. That this more natural process of transpiration and nutrient supply is an improvement was indicated by the renewed vigor and growth which invariably followed this treatment. The stalk was next removed from the nitrite solution, the boot was stripped off and the cane was again planted in the soil at the desired location.

The period required to produce a new root system on a cut stalk, ample for moisture and nutrient requirements, averaged about twenty days.

We have found that cane will flourish for an indefinite period after the new root system appears, regardless of whether the stalk is replanted in the soil or whether the experiment is continued with the roots immersed in the dilute nutrient solution.

Figs. 3 and 4 are photographs of the same specimen, shown in Figs. 1 and 2, after having been replanted in the soil for thirty-three days.

In lieu of using nutrient solution around a portion of the stalk, we have found that moist black sand will answer the same purpose. This latter method is to be

---

* Nitrite solution: 70 grams sodium nitrite were dissolved in 1 liter of tap water and 25 grams of conc. sulphuric acid were added. Ten c.c. of this solution were diluted to 1 liter with tap water and constitutes the "nitrite" solution mentioned in this paper.

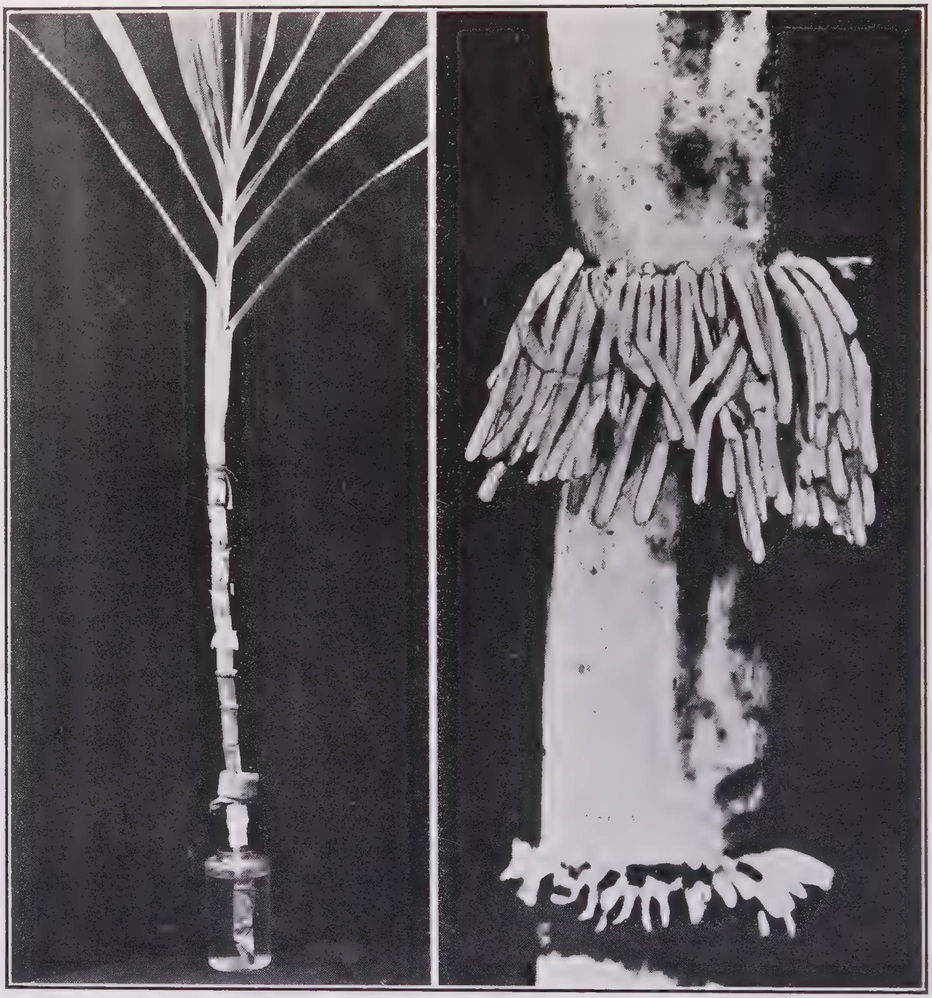


Fig. 1 Fig. 2

Fig. 1. Roots grown on H 109 cane which has been detached from the stool. The cut end of the stalk was covered with a ''nitrite'' solution until the twentieth day of the experiment. Roots appeared on the fifth day and were photographed four days later. The rubber boot shown above the jar was emptied of its contents and rolled down from the roots for photographing.

Fig. 2. An enlargement of the root section visible in Fig. 1.

Fig. 3 Fig. 4

Fig. 3. Showing development of the same specimen thirty-three days after replanting in the soil.

Fig. 4. Enlargement of root system shown in Fig. 3.

preferred, since the granular character of the sand permits free circulation of air and obviates the necessity of artificial air supply for the growing roots. The only attention these modified experiments required was the occasional addition of tap water to the sand in the boot. A data sheet of the history of the cut plant shown in the illustration is included as "Data of Specimen No. 606."

Summary

This paper deals with an attempt to maintain growing conditions in a cane shoot following its detachment from the parent stool.

Preservation by movement of various solutions upward through the cut end of the stalk is discussed.

A simple method of maintaining life and securing renewed growth after detachment is outlined.

DATA OF SPECIMEN NO. 606

Duration of Experiment in Days	Remarks
0	Stalk cut from stool and cut end immersed in nitrite solution.
11	Boot containing dilute nutrient solution placed around middle section of bare stalk.
16	Roots appeared at uppermost nodes covered by boot. Continuous supply of oxygen started bubbling through nutrient solution.
21	Boot emptied and rolled down. Entire specimen photographed (Figs. 1 and 2).
33	Nitrite solution removed from cut end of stalk because movement of solution to the plant ceased through this agency. Moisture requirements of plant now being supplied entirely from the newly developed root system.
40	Boot removed. Specimen planted in soil.
73	Specimen removed from soil.
74	Experiment concluded. Specimen photographed. Figs. 3 and 4.

TABLE

Immersion Media in the Preservation of Cane

Solution Employed	Remarks	Result	Period of Cane Life
.03% sulphurous acid	Employed previously by Das. Still remains the best available medium in its class.	Satisfactory in most cases	40 to 50 days
Nitrite solution (.05% nitrous acid)	A close second to sulphurous acid. Duration of growth commonly exceeds 4 to 5 weeks, with greener leaves than sulphurous acid treatment produces.	Satisfactory in most cases	30 to 45 days
Dilute nutrient solution	Rapid transpiration through cut end introduces toxic amounts of nutrients.	Failure	10 to 12 days
Tap water	Bacterial action on cut end closes vascular bundles.	Failure	1 to 3 days
Calcium sulphite and tap water	Intended to liberate a slow and continuous supply of sulphurous acid by reaction of plant acids with calcium sulphite.	Not entirely satisfactory	10 to 12 days
Tap water plus trace copper carbonate	Action of metallic salt was intended to keep down bacterial growth and thus permit tap water to pass unhindered up through the stalk.	Not entirely satisfactory	10 to 12 days
Tap water plus metallic copper spiral	The minute solubility of metallic copper in water exposed to air is sufficient to prevent growth of algae in water reservoirs and in fish aquariums.	Partly satisfactory	6 to 8 days
Tap water containing 2½ to 10% of a saturated solution of gum camphor	Anti-bacterial action desired.	Failure	3 to 4 days
Tap water containing 25% of a saturated solution of salol	Salol is used in medicine as an intestinal antiseptic. The dilute solution employed in this case did inhibit bacterial growth but its effect on the cane was toxic.	Failure	2 to 3 days
Tap water containing 1% of a saturated solution of white arsenic	Another successful attempt to prevent bacterial growth but with disastrous effect on the cane.	Failure	3 to 4 days
Sand saturated with various combinations of the solutions already enumerated	The plan of these experiments was to secure the effect of the various preservatives in the absence of light.	Failures in every case	2 to 10 days
107 combinations of the various solutions listed in this table	Mechanical and chemical devices of various kinds were used to maintain an hydrostatic head of solution at the immersed end of the stalk.	Partly successful in some cases but no results are worthy of description	2 to 50 days

The Composition of the Pineapple Plant at Various Stages of Growth*

By G. R. Stewart, E. C. Thomas and John Horner.

In considering the problem of fertilizing many agricultural crops it has been found desirable to determine the amounts of soil nutrients absorbed during the growth of the individual crop. Such data can not be used as an exact guide to the amount of fertilizer that is to be applied. A number of crops give an increased yield with smaller amounts of one or more of the major nutrients, than the crop uses during its entire growth. The final test of any problem in fertilization is best obtained by a series of properly laid out field trials. It is, however, of interest to know not only the total quantities of the major nutrients that are used by a crop, but also the period in the growth of the plant at which these nutrients are taken up.

Numerous studies of plant composition have been made upon the major agricultural crops. Several investigations have been carried out of the nutrients taken up by the maize plant at different periods in the growth of the crop. An early study of the periodic absorption of soil nutrients by this crop was conducted by Schweitzer (5) in Missouri, and a more comprehensive study was made later by Jones and Huston (3) at the Indiana Station. Willfarth, Römer and Wimmer (6) determined the composition of barley, wheat and potatoes at various periods in the growth of these crops. Burd (2) made a careful study of the rate of absorption of plant nutrients at short intervals in the growth of the barley crop in California.

Schweitzer noted that there was a rapid absorption of nitrogen at an early stage in the growth of the maize plant. Jones and Huston found a steady increase in the amount of nitrogen contained in the entire maize plant, up to the time when the plant was sufficiently mature to cut for silage. From this time on there was no further gain in nitrogen. They found also an early absorption of potash commencing just before the heads of grain had formed. This period of absorption of potash ended shortly before the plant was mature and was succeeded by a definite loss of potash in the final stage of growth. This final loss of potash was believed to be due to the leaching action of rain upon the potash salts in the leaves as observed previously by Le Clerc and Breazeale (4).

Willfarth, Römer and Wimmer found a rapid, early absorption of nitrogen and potash in barley and wheat plants, followed by a period of some loss of these constituents. They did not find an appreciable variation in the rate of extraction of nutrients from the soil by potatoes and no evidence of a final loss. Burd found a rapid absorption of nitrogen and potash by the barley plant at an early stage of growth. This was followed by a period of loss and finally by a later period of increased absorption. The conditions of the experiment precluded loss by leach-

* This paper covers the completion of some investigations that were unfinished at the close of a contract between the Association of Hawaiian Pineapple Canners and the H. S. P. A.

ing. It was therefore concluded that the results pointed to a return of nitrogen and potassium either to the roots or to the soil.

We have found no record of similar experiments with the pineapple crop. The study reported here was accordingly started in February, 1922, as part of the chemical work carried on for the Association of Hawaiian Pineapple Canners. The investigation was planned to give information as to how rapidly and in what amounts the pineapple plant removes nutrients from the soil. The experiment was carried on at the Kapalama plots of the Pineapple Experiment Station. The planting and cultivation of the plants was in charge of R. E. Doty and W. A. Wendt of the agricultural department of the Pineapple Experiment Station.

Scheme of the Experiment

Two plots were laid out in one of the sections of the Station where the soil was apparently uniform in texture and depth. Each plot was planted with pineapple crowns, as this type of planting material is more uniform in size than pineapple suckers and slips. The crowns in one plot were planted in bare soil and in the other in mulching paper. In each case the two row system of planting was used in which pairs of rows are planted 6½ feet apart from center to center. The two rows of each pair were spaced 22 inches apart and the individual plants were set 18 inches distant in the row on the usual staggered scheme.

Before planting, the soil in each row received an application of mixed fertilizer at the rate of 650 pounds per acre. This fertilizer had the following composition: 12 per cent total nitrogen of which 7½ per cent was derived from ammonium sulfate, 4 per cent from dried blood and ½ per cent from bone meal; 6¼ per cent phosphate, expressed as P_2O_5, derived from fine ground steamed bone meal; 3 per cent potash expressed as K_2O derived from sulfate of potash.

This preliminary fertilization was followed by a top fertilization of dried blood in April, 1923, and a side dressing of ammonium sulphate at the rate of 350 pounds per acre in June, 1923. This completed the fertilization prior to fruiting. After the plants fruited in December to January, 1924, the ratoon crop received a fertilization of 750 pounds per acre of the same mixed fertilizer that was applied before the plots were planted. The following table summarizes the applications to the plant and ratoon crops:

FERTILIZATION OF THE PLANT CROP

Date of Application	Amount of Fertilizer per Acre	Plant Food Applied per Acre: Nitrogen N (lbs.)	Phosphate P_2O_5 (lbs.)	Potash K_2O (lbs.)
Feb. 10, 1922	Mixed fertilizer—650 lbs.	78.00	42.25	19.50
April 1, 1923	Dried blood—250 pounds	33.75	....	....
June 1, 1923	Ammonium sulphate—350 lbs.	71.75	....	....
	Total for plant crop	183.50	42.25	19.50

FERTILIZATION OF THE RATOON CROP

Date of Application	Amount of Fertilizer per Acre	Nitrogen N (lbs.)	Phosphate P_2O_5 (lbs.)	Potash K_2O (lbs.)
March, 1924	Mixed fertilizer—750 lbs.	90.00	48.75	22.5

Six of the crowns were taken for analysis from the selected material before planting. At three-month intervals after this, six uniform plants were harvested from both the paper and no paper plots. The plants were weighed and then washed or wiped rapidly to remove adhering soil. The pineapple plant has a distinctly glaucous smooth surface so it is not believed that the solvent action of the water introduced as great a factor of error as would have been introduced had the adhering silt been included in the analytical sample.

After cleaning and weighing the plants they were separated into the leaves and the stems and the weight of each was determined. A representative sample of each was then cut into small portions and dried at 80 to 85° C. The dried sample was ground and a composite sample of leaves and stems was made up. The percentage of nitrogen, lime, phosphate, potash and sulphur was determined in these composite samples of leaves and stems. From this data the composition of the original plants was computed. In addition, the percentage of ash, nitrogen and sulphur was determined in all the individual samples of leaves in order to give some basis for estimating the variability of the constituents in the individual plants. Composite samples of the ash of the leaves of the pineapple plants harvested at each stage of growth were subjected to a more complete analysis. This consisted of the additional determinations of silica, magnesia, sodium, iron, alumina, manganese, sulphate, chlorides and carbonates.

The plants fruited at the age of 21 to 23 months. Our harvesting of plants at 15 months of age included three plants from the paper plot which had begun to form fruit and two from the bare soil plots which were fruiting. At 18 months of age, 5 out of 6 plants from each plot were forming fruit. This corresponded very closely with the determined percentage of plants which finally fruited. On both plots 80 to 85 per cent of the plants fruited in the plant crop. In the harvesting of the plants at 21 months of age 3 out of 6 plants on each plot had partly ripe fruit. A portion of the fruit had already ripened and been removed.

Owing to the fact that we had removed part of the plants from each plot by our periodic harvesting, it was impossible for us to determine the yield of the plant crop upon the actual plots used for our study. The adjoining plots of Smooth Cayenne, which had received the same fertilization, gave a yield of 18 tons of fruit per acre on the plant crop. This yield was obtained under mulching paper. In our experimental plots the same per cent of the plants on the paper and no paper plots fruited. The fruits from the no paper plot were appreciably smaller in size. This difference in size was sufficient to make the crop from the no paper plots amount to 16 tons per acre.

After the plant crop had been harvested the ratoons were fertilized with mixed fertilizer at the rate of 750 pounds per acre. This application was made at the time the plants were approximately 26 months of age. We harvested plants at 27 months of age, and 3 months later at 30 months of age. Up to this time the growth of the plants had been entirely normal, though the ratoons were not making so vigorous a growth as the plant crop had done. After this harvesting the ratoons deteriorated rapidly and in the early fall there were indications of wilt

in both plots. The plants did not fail entirely, but it was decided that their growth was no longer normal. The harvesting of the plants was therefore not continued beyond 30 months of age.

Growth of the Pineapple Plants

The growth of the plants is shown by the weights obtained at each harvesting period. These data are given in Table I and are presented also graphically in Fig. 1. In Table I, the weight of the individual crowns and plants is given for each period of harvesting. The mean weight is shown, also, together with the probable error of the mean computed by Bessel's formula. This probable error of the mean is the variation from the mean, plus or minus, within which half of the results will fall. A consideration of this figure together with the weights of the individual plants will enable one to make an estimate of the variability in growth which occurred in our plots. At most of the sampling periods the weights of the individual plants showed a moderately close agreement, but after 12 months of age there were occasional plants which varied widely in size from the group in which they were collected. We shall see later, however, that a variation in size is not accompanied by a corresponding variation in certain of the major constituents which we have determined individually. We therefore do not believe that the variability of the plants in size introduces a large error in our final calculation of the abstraction of nutrients by the crop.

The graphic representation of the mean weight of the plants at each period shows clearly that the plants raised on the paper plots were larger at each period of sampling up to the maturing of the fruit at 21 to 23 months of age. After this time the ratoons are more similar in size. We shall not attempt to draw any close deductions from this fact, owing to the partial failure of the ratoons at a later stage of development. The weight of the plants reported in Table I does not include the roots, nor fruit, when any was harvested. The roots were excluded, as we did not find it feasible to clean them of adhering soil by any method other than prolonged soaking in water, which caused appreciable alteration of the root tissues. The number of fruit harvested by us at any period was too small to form an accurate basis for a graphic representation of the development of the fruit. We shall only attempt to give an approximate estimate later of the extraction of nutrients during the growth of the fruit, with an accurate figure for the final amount taken up by the fruit harvested on the plant crop.

In Table II, we have recorded the mean weight of leaves and stems for the plants harvested from each plot at the various sampling periods.

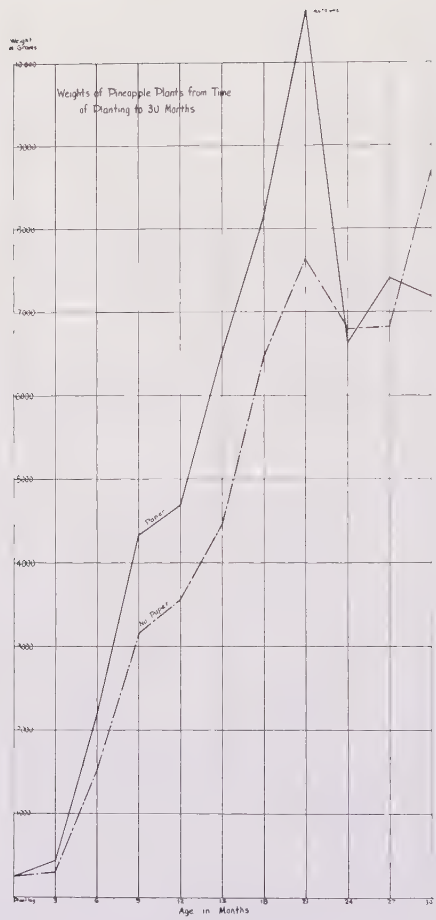


Fig. 1. Comparative growth of pineapple plants from time of planting to thirty months, with and without paper.

TABLE I

Weight of Pineapple Plants from Planting to Thirty Months of Age

Age	No Paper Grams		No Paper Pounds	Paper Grams	Paper Average Weight Grams	Paper Pounds
Crown	244		0.5			
Crown	269		0.6			
Crown	215		0.5			
Crown	287		0.6			
Crown	243		0.5			
Crown	210		0.5			
Mean Weight	245	± 7.3	0.5			
3 Months	330		0.7	395		0.9
3 Months	307		0.7	507		1.1
3 Months	250		0.5	476		1.0
3 Months	280		0.6	419		0.9
3 Months	269		0.6	437		1.0
3 Months	393		0.9	455		1.0
Mean Weight	305	± 13.9	0.7	449	± 7.4	1.0
6 Months	1656		3.6	2174		4.8
6 Months	1245		2.7	2105		4.6
6 Months	1493		3.3	2384		5.2
6 Months	1583		3.5	2193		4.8
6 Months	1555		3.4	2109		4.6
6 Months	1617		3.6	2113		4.6
Mean Weight	1525	± 40.3	3.4	2180	± 85.2	4.8
9 Months	2529		5.6	4177		9.2
9 Months	3568		7.9	3352		7.4
9 Months	2825		6.2	4920		10.8
9 Months	3426		7.5	4642		10.2
9 Months	2966		6.5	4428		9.8
9 Months	3652		8.0	4363		9.6
Mean Weight	3160	±127.0	7.0	4314	±147.0	9.5
12 Months	3339		7.4	4368		9.6
12 Months	4174		9.2	4300		9.5
12 Months	3914		8.6	3650		8.0
12 Months	2562		5.6	5082		11.2
12 Months	2939		6.5	5020		11.1
12 Months	4373		9.6	5674		10.5
Mean Weight	3550	±198.0	7.8	4683	±196.0	10.3
15 Months	4195		9.2	6907		15.2
15 Months	4154		9.1	7405		16.3
15 Months	4806		10.6	5408		11.9
15 Months	4080		9.0	6220		13.7
15 Months	4750		10.5	6832		15.1
15 Months	4732		10.4	6304		13.9
Mean Weight	4453	± 94.0	9.8	6513	± 75.0	14.3

18 Months	6265		13.8	8645		19.0
18 Months	7075		15.6	7100		15.6
18 Months	7665		16.9	6757		14.9
18 Months	6640		14.6	7690		16.9
18 Months	5671		12.5	10270		22.6
18 Months	5650		12.4	8445		18.6
Mean Weight	6494	±221.0	14.3	8151	±462.0	17.9
21 Months	6922		15.3	9552		21.0
21 Months	6226		13.7	13908		30.7
21 Months	5719		12.6	12965		28.6
21 Months	6016		13.3	11977		26.4
21 Months	9407		20.7	5757		12.7
21 Months	11504		25.4	9860		21.7
Mean Weight	7632	±639.0	16.8	10670	±805.0	23.5
24 Months	7607		16.8	5508		12.1
24 Months	8012		17.7	6499		14.3
24 Months	4500		9.9	7593		16.7
24 Months	7260		16.0	7740		17.1
24 Months	6054		13.3	6752		14.9
24 Months	7342		16.2	5659		12.5
Mean Weight	6795	±360.0	15.0	6625	±258.0	14.6
27 Months	6173		13.6	6947		15.3
27 Months	7634		16.8	6488		14.3
27 Months	6573		14.5	5765		12.7
27 Months	8070		17.8	7916		17.4
27 Months	5990		13.2	11241		24.8
27 Months	6538		14.4	6081		13.4
Mean Weight	6829	±231.0	15.0	7406	±557.0	16.3
30 Months	6209		13.7	8655		19.1
30 Months	8119		17.9	7833		17.3
30 Months	10755		23.7	4626		10.2
30 Months	7091		15.6	8534		18.8
30 Months	9706		21.4	7929		17.5
30 Months	10220		22.5	5546		12.2
Mean Weight	8683	±505.0	19.1	7187	±464.0	15.8

TABLE II

Relation Between Weights of Leaves and Stem of Plant from Time of Planting to Thirty Months—Weights Expressed in Grams

No Paper Plot

Age	Weight of Leaves	Weight of Stem	Total Weight	Per cent Leaves	Per cent Stem
3 Months	264	41	305	86.56	13.44
6 Months	1381	144	1525	90.56	9.44
9 Months	2775	385	3160	87.81	12.19
12 Months	3085	465	3550	86.90	13.10
15 Months	3629	824	4453	81.50	18.50
18 Months	5302	1192	6494	81.64	18.36
21 Months	5991	1640	7631	78.51	21.49
24 Months	4870	1925	6795	71.67	28.33
27 Months	5078	1751	6829	74.36	25.64
30 Months	6314	2369	8683	72.72	27.28

Paper Plot

3 Months	396	53	449	88.20	11.80
6 Months	1981	199	2180	90.87	9.13
9 Months	3747	567	4314	86.86	13.14
12 Months	4048	635	4683	86.44	13.56
15 Months	5154	1359	6513	79.13	20.87
18 Months	6727	1424	8151	82.53	17.47
21 Months	8284	2386	10670	77.64	22.36
24 Months	4886	1739	6625	73.75	26.25
27 Months	5324	2082	7406	71.89	28.11
30 Months	5062	2125	7187	70.43	29.57

TABLE III

Composition of Pineapple Plants from Time of Planting to Thirty Months—Major Constituents in Original Material

Age	Moisture per cent (H_2O)	Ash per cent	Nitrogen per cent (N)	Sulphur per cent (S)	Potash per cent (K_2O)	Phosphate per cent (P_2O_5)	Lime per cent (CaO)
Crowns before planting	86.35	0.92	0.162	0.024	0.300	0.034	0.105
No Paper Plot							
3 Months	89.24	1.57	0.226	0.033	0.620	0.038	0.135
6 Months	89.24	1.67	0.236	0.034	0.721	0.067	0.130
9 Months	86.08	1.82	0.278	0.053	0.824	0.065	0.134
12 Months	88.16	1.53	0.221	0.048	0.658	0.062	0.114
15 Months	86.00	1.87	0.270	0.047	0.753	0.064	0.118
18 Months	88.79	1.44	0.188	0.036	0.596	0.053	0.116
21 Months	88.01	1.45	0.182	0.042	0.588	0.063	0.127
24 Months	86.55	1.34	0.180	0.043	0.547	0.044	0.118
27 Months	84.34	1.33	0.194	0.048	0.556	0.044	0.115
30 Months	84.69	1.24	0.172	0.044	0.519	0.039	0.139
Paper Plot							
3 Months	88.66	1.50	0.247	0.036	0.521	0.038	0.119
6 Months	89.40	1.62	0.225	0.036	0.653	0.059	0.112
9 Months	86.99	1.61	0.237	0.052	0.723	0.055	0.124
12 Months	88.35	1.53	0.208	0.047	0.652	0.058	0.122
15 Months	86.09	1.88	0.223	0.035	0.731	0.055	0.115
18 Months	87.42	1.64	0.200	0.037	0.688	0.052	0.142
21 Months	88.14	1.44	0.182	0.037	0.592	0.047	0.116
24 Months	85.78	1.36	0.178	0.039	0.520	0.039	0.121
27 Months	85.80	1.23	0.163	0.036	0.522	0.036	0.112
30 Months	84.68	1.34	0.168	0.046	0.567	0.039	0.139

TABLE IV

Individual Variation in Certain Major Constituents of Pineapple Leaves at Three-Month Periods up to Thirty Months of Age

Age	No Paper Plot Moisture per cent	Ash per cent	Nitrogen per cent	Sulphur per cent	Paper Plot Moisture per cent	Ash per cent	Nitrogen per cent	Sulphur per cent
Crown	86.27	0.95	0.15	0.023				
Crown	85.32	0.85	0.16	0.019				
Crown	88.65	0.86	0.18	0.019				
Crown	85.54	0.95	0.16	0.024				
Crown	87.08	1.07	0.16	0.028				
Crown	85.24	0.86	0.17	0.029				
3 Months....	88.87	1.49	0.24	0.029	88.63	1.51	0.24	0.024
3 Months....	88.17	1.39	0.24	0.023	88.93	1.62	0.22	0.023
3 Months....	87.50	1.57	0.27	0.019	88.25	1.70	0.22	0.020
3 Months....	88.24	1.54	0.24	0.022	89.62	1.61	0.22	0.019
3 Months....	87.56	1.53	0.25	0.025	89.54	1.45	0.21	0.020
3 Months....	89.85	1.47	0.23	0.021	89.31	1.55	0.21	0.029
6 Months....	88.65	1.66	0.25	0.028	88.58	1.68	0.21	0.021
6 Months....	89.01	1.61	0.21	0.025	88.91	1.61	0.22	0.021
6 Months....	89.00	1.71	0.22	0.026	89.02	1.68	0.22	0.023
6 Months....	89.42	1.61	0.22	0.022	89.16	1.68	0.24	0.028
6 Months....	89.92	1.52	0.19	0.020	89.25	1.69	0.25	0.028
6 Months....	89.52	1.62	0.20	0.023	89.47	1.64	0.23	0.023
9 Months....	87.50	1.60	0.19	0.041	86.88	1.45	0.24	0.026
9 Months....	88.12	1.60	0.24	0.032	86.88	1.79	0.22	0.034
9 Months....	87.50	1.69	0.22	0.041	86.25	1.87	0.29	0.038
9 Months....	86.25	1.67	0.24	0.041	85.63	2.12	0.31	0.040
9 Months....	87.50	1.68	0.21	0.034	85.63	1.92	0.30	0.040
9 Months....	86.88	1.68	0.24	0.028	85.25	2.01	0.28	0.044
12 Months....	89.40	1.48	0.16	0.030	88.70	1.39	0.20	0.027
12 Months....	89.30	1.56	0.19	0.034	88.50	1.50	0.18	0.037
12 Months....	88.50	1.58	0.22	0.031	88.60	1.56	0.22	0.032
12 Months....	88.50	1.53	0.18	0.034	88.30	1.55	0.20	0.037
12 Months....	89.60	1.38	0.17	0.032	88.50	1.57	0.21	0.033
12 Months....	88.10	1.60	0.21	0.028	89.00	1.58	0.22	0.022
15 Months....	85.50	2.01	0.23	0.025	84.80	2.14	0.32	0.038
15 Months....	86.50	1.99	0.22	0.022	86.70	1.96	0.28	0.025
15 Months....	86.30	1.91	0.21	0.023	86.80	1.91	0.24	0.024
15 Months....	86.00	2.03	0.23	0.017	86.30	1.98	0.27	0.027
15 Months....	87.00	1.72	0.20	0.017	87.00	1.98	0.24	0.028
15 Months....	85.50	2.11	0.23	0.013	86.50	2.00	0.26	0.026
18 Months....	87.30	1.74	0.20	0.028	89.00	1.42	0.17	0.024
18 Months....	87.30	1.77	0.21	0.028	89.00	1.39	0.17	0.024
18 Months....	87.50	1.72	0.20	0.027	88.20	1.53	0.20	0.026
18 Months....	86.70	1.65	0.22	0.024	88.20	1.42	0.19	0.026
18 Months....	86.00	1.75	0.21	0.025	88.20	1.54	0.20	0.026
18 Months....	86.80	1.75	0.17	0.024	88.00	1.62	0.18	0.026

21 Months.... 88.40	1.47	0.17	0.025	87.30	1.69	0.20	0.028
21 Months.... 88.50	1.40	0.17	0.025	88.30	1.38	0.19	0.026
21 Months.... 88.40	1.46	0.18	0.025	88.10	1.50	0.18	0.026
21 Months.... 88.00	1.64	0.18	0.022	87.60	1.72	0.21	0.027
21 Months.... 88.30	1.57	0.19	0.021	88.70	1.40	0.15	0.025
21 Months.... 87.30	1.63	0.19	0.023	87.80	1.58	0.18	0.027
24 Months.... 86.90	1.53	0.19	0.020	87.10	1.34	0.19	0.021
24 Months.... 85.80	1.71	0.19	0.021	88.30	1.18	0.15	0.019
24 Months.... 86.80	1.42	0.16	0.020	87.50	1.39	0.17	0.020
24 Months.... 86.70	1.48	0.16	0.021	86.80	1.37	0.18	0.021
24 Months.... 85.80	1.51	0.18	0.023	87.80	1.43	0.17	0.019
24 Months.... 86.80	1.33	0.16	0.021	87.80	1.28	0.15	0.019
27 Months.... 85.20	1.45	0.17	0.024	85.00	1.20	0.15	0.024
27 Months.... 86.80	1.26	0.16	0.021	84.40	1.69	0.20	0.025
27 Months.... 86.40	1.22	0.15	0.022	85.70	1.30	0.18	0.023
27 Months.... 85.50	1.42	0.16	0.022	86.20	1.38	0.17	0.026
27 Months.... 87.40	1.32	0.15	0.019	85.60	1.72	0.20	0.027
27 Months.... 86.50	1.29	0.15	0.020	86.30	1.37	0.17	0.026
30 Months.... 87.50	1.31	0.16	0.024	85.90	1.20	0.16	0.022
30 Months.... 86.20	1.33	0.16	0.026	85.00	1.34	0.16	0.024
30 Months.... 86.20	1.45	0.16	0.026	85.40	1.27	0.17	0.023
30 Months.... 82.00	1.54	0.17	0.034	86.40	1.22	0.15	0.023
30 Months.... 86.00	1.34	0.15	0.027	84.20	1.47	0.16	0.026
30 Months.... 85.80	1.42	0.16	0.027	87.50	1.29	0.14	0.021

The results indicate that there was essentially the same relation between the weights of leaves and stems in the plants harvested from the two plots. In other words, the plants harvested from the paper plot were larger in both leaf and stem development, up to the time of first fruiting, than the corresponding plants grown on bare soil.

Composition of the Pineapple Plants

The analyses of the pineapple plants were made according to the methods of the Association of Official Agricultural Chemists (1). The composition of the composite samples of the entire plants, calculated to the original material, as harvested, is given in Table III. It will be seen that the composition of the plants grown on the "no paper," and "paper" plots was essentially the same at each period of growth. There was, however, an appreciable variation in the percentages of part of the major constituents present in the pineapple plants from the earlier periods to the final samples collected. Nitrogen was present in appreciably larger percentages during the first 15 to 18 months of the plants' growth. Sulphur appears to have been present in larger percentages at about the ninth to twelfth month. Potash was present in higher percentages from the ninth to the fifteenth month than it was in the latter part of the sampling periods. Phosphates were present in larger percentages from the sixth to the twenty-first month than in the last periods sampled. Lime appeared to be present in essentially the same amounts at all periods. Besides these variations in the composition of the plants during the growing period, the original crowns had a lower content of total ash, total nitrogen, total sulphur, and total potash, than was found in the growing plants.

TABLE V

Composition of Ash of Pineapple Leaves from Time of Planting to Thirty Months—Calculated to Per Cent on Water Free Basis

Crowns	Silica (SiO_2)	Phosphates (P_2O_5)	Potash (K_2O)	Lime (CaO)	Magnesia (MgO)	Sodium (Na_2O)	Iron Oxide (Fe_2O_3)	Aluminum Oxide (Al_2O_3)	Manganese (Mn_3O_4)	Sulphate (SO_3)	Chloride (Cl)	Carbon Dioxide (CO_3)	
Crowns	5.45	3.79	32.60	11.06	5.47	5.33	0.76	1.78	.....	3.44	13.57	11.08	(Whole Plant)
No Paper Plot													
3 Months....	8.69	1.93	37.23	5.16	6.21	5.05	1.80	1.78	0.37	2.80	13.81	13.91	
6 Months....	6.07	2.89	42.09	5.72	6.69	4.47	0.59	0.45	0.36	2.16	8.70	14.79	
9 Months....	8.30	2.98	46.68	5.52	5.40	5.16	2.17	0.93	0.80	2.06	8.86	13.86	
12 Months....	9.57	2.98	44.76	5.52	5.49	3.96	2.04	1.31	0.80	2.06	9.22	12.99	
15 Months....	9.66	2.54	40.47	5.61	5.40	8.24	1.14	0.70	0.59	4.63	7.64	15.20	
18 Months....	10.61	2.76	41.90	8.39	5.56	4.60	1.26	1.18	0.66	2.82	8.96	10.79	
21 Months....	11.30	2.60	42.45	6.23	6.06	5.05	1.34	2.18	0.70	1.80	9.87	12.42	
24 Months....	9.14	2.22	40.85	8.21	5.84	9.45	2.32	1.14	0.89	2.14	10.88	10.75	
27 Months....	10.28	2.37	43.90	7.54	5.50	6.90	1.28	1.42	1.03	2.10	9.72	11.67	
30 Months....	....	2.27	44.05	8.01	....	....	....	....	....	....	....	....	
Paper Plot													
3 Months....	7.37	1.95	42.41	6.19	6.01	3.74	1.44	0.79	0.52	2.19	11.79	14.41	
6 Months....	6.74	3.21	44.98	6.72	5.91	4.47	0.77	0.44	0.42	2.51	7.77	14.74	
9 Months....	7.50	3.00	46.86	5.26	5.23	4.46	2.23	0.52	0.70	2.24	7.62	16.40	
12 Months....	9.47	3.32	45.82	5.21	5.30	3.78	1.79	1.46	0.80	2.26	7.98	13.43	
15 Months....	9.55	2.56	41.07	5.61	5.37	10.00	0.92	0.48	0.49	2.75	7.43	15.05	
18 Months....	10.55	3.14	41.75	7.44	6.15	3.70	1.22	1.50	0.79	2.40	8.38	14.24	
21 Months....	13.15	2.98	41.58	6.46	6.10	4.15	1.18	2.02	0.67	1.96	9.03	12.54	
24 Months....	8.04	2.65	44.50	7.08	5.52	5.54	1.38	0.52	0.95	1.92	10.38	13.23	
27 Months....	11.34	2.63	42.90	7.18	6.06	4.55	2.10	1.00	0.80	2.26	10.16	11.76	
30 Months....	....	2.40	44.15	9.00	....	....	....	....	....	....	....	....	

In Table IV is given the individual variation of the plants in moisture, ash, nitrogen and sulphur at each period of harvesting. It will be seen that there was only a small variation in the amounts of these constituents among the plants of one sampling period. These results appear to us to indicate that the individual plants from the same plot did not vary significantly from each other in the major constituents at the same period of harvesting.

It was originally planned to make more complete analyses of the ash of both the stems and leaves of the pineapple plants at each period of sampling. Owing to the press of other work this was only carried out upon the composite samples of the ash of the leaves. These data are presented in Table V. The composition of the ash of the leaves from both groups of plants is essentially the same at similar ages of the plants. At part of the periods of harvesting the plants from the paper plot showed a higher content of potash in the ash than did the plants from the no paper plots. At most of the periods of harvest there was a slightly higher content of phosphates in the ash of the leaves of the paper plot plants. Beyond these slight differences there is little consistent variation between the plants from the two plots.

The largest constituent of the ash of the leaves of the plants from both plots was potash. Next in amount was carbon dioxide in the form of carbonates, followed then by silica. The content of chlorides was unexpectedly high, while lime and magnesia were present in approximately equal quantities. There was only a moderate per cent of sodium in the ash and the amount of phosphate was comparatively small.

Composition of the Fruit

The compositions of the fruits harvested at 15 months, 18 months and 21 months were all determined. The fruits obtained at 15 months of age were small and immature, averaging 651 grams or 1.4 pounds on the "no paper" plot and 723 grams or 1.6 pounds on the paper plot. The green fruit collected at 18 months of age averaged 1,852 grams or 4.0 pounds on the "no paper" plot and 2,108 grams or 4.6 pounds on the paper plot. The ripe fruit collected at 21 months of age, averaged 2,658 grams or 5.9 pounds on the "no paper" plot, and 2,973 grams or 6.6 pounds on the paper plot. This figure can only be regarded as approximate on account of the comparatively small number of individual fruits which were weighed. We shall, however, use it as an estimate of the approximate development of the fruit crop at the early portion of the development of the pineapple.

We found in checking the calculations for the composition of the pineapple fruit that the moisture figures were discordant, pointing to the fact that fermentation had taken place in drying the samples. We accordingly obtained another set of fruits from adjoining plots at Kapalama, which had received the same fertilization as our plots. On these fruits all moisture determinations were made at 70° Centigrade, in a vacuum oven, upon representative portions of the entire fruit, obtained as soon as the fruits were cut open. The figures obtained on these samples showed a close agreement with each other. No green fruit was obtainable at this time in any quantity at Kapalama. We accordingly obtained a series of ripe

half ripe, and green fruit from the plots of the Pineapple Experiment Station at Wahiawa, where the fertilization had been the same as that employed on our plots. We found the analytical results obtained on the ripe fruit were in extremely close agreement with the figures we had obtained on the ripe fruit from Kapalama. The results upon the green fruit have therefore been used by us, in our calculations later on, of the amounts of plant nutrients present in the fruit at 15 and 18 months of age.

The compositions of the three sets of fruit collected from the plots at Wahiawa which had received the same fertilization as our experiment are given in Table VI. It will be seen that the green fruit was consistently higher in moisture content than the half ripe and ripe fruit. There is no large change in the percentage of any of the important nutrients in the periods of sampling included in the table. It will be seen that potash is present in notably larger amounts than any of the other plant nutrients. Next in amount comes nitrogen, then lime and phosphates.

Amounts of Plant Nutrients Removed by Pineapple Crops

From our previous Table III, we have calculated the amounts of plant nutrients removed per acre by our two groups of pineapple plants. Such a calculation should be regarded as giving only an approximate figure. In order to obtain more exact data it would be necessary to sample a much larger number of plants at each harvesting period. This was not feasible so we are submitting our estimate for such value as it may have in the study of fertilizer needs of the pineapple crop.

The extraction of nitrogen, lime, phosphate, potash and sulfur is given in Table VII, for the plants exclusive of roots and fruit. These data have been computed on the basis of 7,350 plants per acre. The same data have been arranged graphically in Figs. 2 and 3. It is very evident that potash is drawn upon in the largest amounts at all periods of growth. Next in order of absorption was nitrogen, then lime, and after this, phosphate.

TABLE VIII

Weight of Pineapple Fruit per Acre and Pounds of Plant Nutrients Removed

No Paper Plot

Period of growth of plant and condition of fruit	Pounds of fruit per acre	Nitrogen N lbs. per acre	Lime CaO lbs. per acre	Phosphate (P_2O_5) lbs. per acre	Potash K_2O lbs. per acre
15 months, green fruit....	7635	6.5	3.3	1.9	15.9
18 months, green fruit....	21816	18.8	9.4	5.7	44.3
21 months, ripe fruit......	32000	24.9	11.8	8.3	66.9

Paper Plot

Period of growth of plant and condition of fruit	Pounds of fruit per acre	Nitrogen N lbs. per acre	Lime CaO lbs. per acre	Phosphate (P_2O_5) lbs. per acre	Potash K_2O lbs. per acre
15 months, green fruit....	8726	7.5	3.7	2.3	17.7
18 months, green fruit....	25088	21.6	10.8	6.5	21.6
21 months, ripe fruit......	36000	27.6	13.3	9.3	75.2

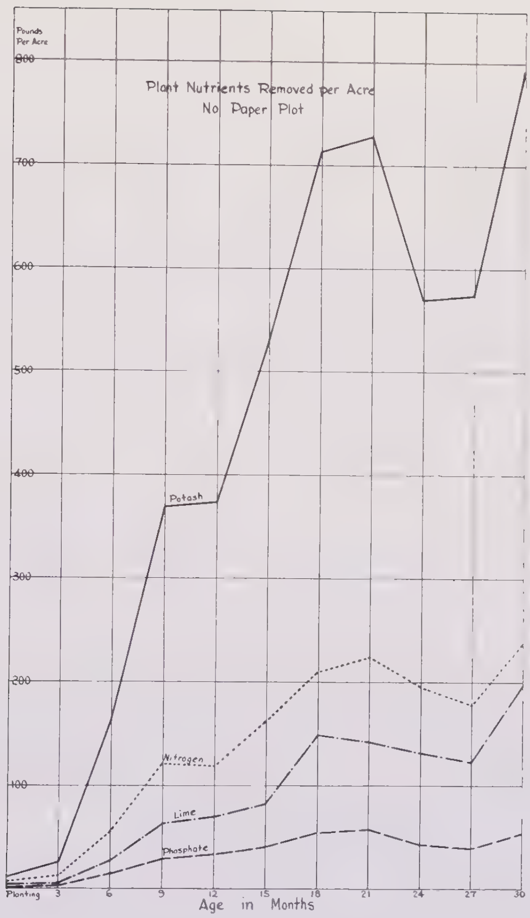


Fig. 2. Abstraction of nutrients per acre. No paper plot.

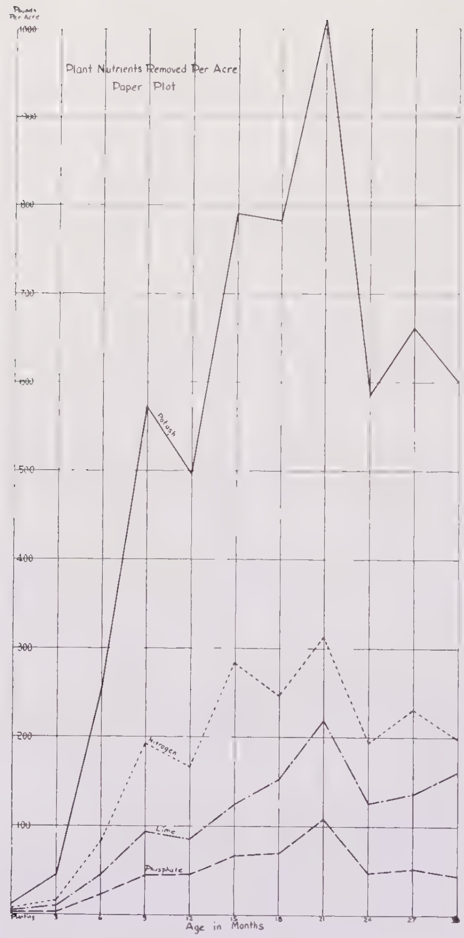


Fig. 3. Abstraction of nutrients per acre. Paper plot.

TABLE VI

Composition of Pineapple Fruit from Wahiawa

Results Expressed as Per Cent in Original Fruit

No. of fruit	Condition of fruit	Moisture	Nitrogen N	Ash per cent	Silica SiO_2	Phosphate P_2O_5	Calcium CaO	Sulfate SO_3	Potash K_2O	Sodium Na_2O	Magnesium MgO	Chloride Cl	Carbon Dioxide CO_2
1	Ripe	83.2	0.075	0.58	0.013	0.023	0.032	0.028	0.189	0.022	0.019	0.040	0.105
2	Ripe	83.8	0.080	0.52	0.015	0.026	0.037	0.017	0.235	0.022	0.017	0.029	0.129
3	Ripe	84.2	0.081	0.60	0.020	0.032	0.047	0.138	0.204	0.025	0.026	0.031	0.134
4	Ripe	83.5	0.077	0.57	0.015	0.025	0.036	0.167	0.208	0.024	0.024	0.040	0.118
5	Ripe	82.1	0.072	0.55	0.009	0.029	0.036	0.014	0.219	0.027	0.016	0.036	0.099
6	Ripe	83.3	0.086	0.68	0.013	0.025	0.036	0.014	0.204	0.022	0.024	0.036	0.125
Ripe fruit mean composition		83.3	0.078	0.58	0.014	0.026	0.037	....	0.209	0.025	0.021	0.035	0.118
7	Half ripe	84.9	0.091	0.65	0.012	0.025	0.029	0.025	0.222	0.026	0.020	0.031	0.091
8	Half ripe	83.4	0.082	0.50	0.014	0.025	0.030	0.024	0.212	0.020	0.021	0.026	0.107
9	Half ripe	86.1	0.082	0.65	0.017	0.031	0.030	0.026	0.243	0.034	0.020	0.023	0.117
10	Half ripe	84.8	0.088	0.58	0.019	0.028	0.040	0.033	0.216	0.023	0.023	0.024	0.128
11	Half ripe	85.7	0.099	0.53	0.013	0.026	0.030	0.019	0.208	0.027	0.019	0.028	0.121
12	Half ripe	83.2	0.081	0.53	0.014	0.032	0.031	0.018	0.220	0.017	0.021	0.028	0.121
Half ripe fruit mean composition		84.7	0.087	0.57	0.015	0.028	0.031	0.024	0.220	0.024	0.021	0.026	0.114
13	Green	91.7	0.087	0.49	0.018	0.028	0.038	0.020	0.178	0.014	0.020	0.025	0.113
14	Green	89.6	0.085	0.60	0.023	0.029	0.042	0.025	0.243	0.034	0.024	0.025	0.134
15	Green	90.0	0.103	0.65	0.014	0.028	0.037	0.023	0.225	0.017	0.023	0.028	0.111
16	Green	86.9	0.069	0.56	0.016	0.022	0.038	0.034	0.204	0.027	0.022	0.026	0.116
17	Green	91.6	0.084	0.56	0.018	0.025	0.052	0.030	0.183	0.016	0.024	0.032	0.117
18	Green	88.5	0.087	0.47	0.015	0.023	0.050	0.030	0.185	0.023	0.022	0.027	0.115
Green fruit mean composition		89.7	0.086	0.55	0.017	0.026	0.043	0.027	0.203	0.022	0.022	0.027	0.118

TABLE VII

Major Plant Foods Removed per Acre by Pineapple Plants from Time of Planting to Thirty Months—Calculated in Pounds per Acre

No Paper

Age	Nitrogen (N)	Lime (CaO)	Phosphate (P_2O_5)	Potash (K_2O)	Sulphur (S)
Crowns	6.4	4.1	1.3	11.8	0.9
3 Months	12.1	5.8	1.9	25.7	1.8
6 Months	55.2	27.7	14.4	160.3	8.8
9 Months	120.8	63.1	28.0	368.5	26.4
12 Months	119.2	70.1	33.0	372.8	26.7
15 Months	161.9	83.6	40.1	529.3	25.0
18 Months	209.3	148.8	54.2	713.6	38.7
21 Months	224.0	142.2	57.6	728.2	45.7
24 Months	194.9	132.1	43.1	569.9	43.2
27 Months	178.9	122.9	39.6	574.7	39.7
30 Months	234.9	195.5	54.2	793.3	64.8

Paper

Age	Nitrogen (N)	Lime (CaO)	Phosphate (P_2O_5)	Potash (K_2O)	Sulphur (S)
3 Months	16.3	9.8	2.7	44.9	2.4
6 Months	83.1	45.7	23.7	253.2	12.0
9 Months	193.2	93.4	45.4	573.4	36.8
12 Months	166.4	85.9	46.6	496.4	36.2
15 Months	283.4	124.1	66.9	790.9	49.3
18 Months	247.3	152.7	69.5	782.9	48.0
21 Months	313.5	219.0	108.9	1010.5	72.7
24 Months	192.7	125.5	47.5	584.5	45.7
27 Months	231.6	137.7	52.7	663.4	57.0
30 Months	199.0	161.4	44.7	601.1	51.0

The maximum absorption of nutrients took place at the time the plants fruited, at approximately 21 months of age. It should be remembered that the individual pineapple plant still continues to grow to form the ratoon plant. After fruiting the top of the former plant dies back, but a series of shoots come out at the base of the plant to furnish new fruiting material. Part of these shoots are ordinarily removed for planting stock and two of the strongest shoots are left to bear the ratoon fruits. Our plants sampled at 24 months of age were just at the period of the old top dying back, while at 27 and 30 months of age the ratoon plant was beginning to develop more vigorously. Owing to the later partial growth failure which occurred in our plots, the results obtained by us can be considered to be reliable, only, through the period of fruiting and maturing the plant crop.

In Table VIII we give an estimate of the removal of plant nutrients by the development of pineapple fruit at three periods of growth, 15, 18 and 21 months. The amounts of nutrients taken up by the fruit are small when they are compared with those abstracted from the soil by the pineapple plant. The relative absorption of the major nutrients, however, was in the same order as that which was shown for the plant in Table VII. In other words, the heaviest demand was upon the potash, which was taken up to more than twice the extent that nitrogen, the next largest constituent, was drawn upon.

Deductions from the Analyses

It will be seen by consulting the schedule of fertilization that the nitrogen and phosphate applied to the crop in our experiment approach the amounts used by the pineapple plants up to the time of fruiting. The great discrepancy between fertilization and plant consumption is in the large amount of potash taken up by the crop and the small amount applied in the fertilizer. Since the time we carried out this work the applications of mixed fertilizer to pineapple crops have steadily increased. We are informed by H. L. Denison, agriculturist of the Pineapple Experiment Station, that the present fertilization will ordinarily consist of applying from 500 to 750 pounds of mixed fertilizer before planting. This is followed by a like application, later in the first season. One or more applications of mixed fertilizer are put on during the second season so that 1,500 to 2,500 pounds of fertilizer are put in prior to the time of fruiting.

After the plant crop matures, one or two applications of mixed fertilizer, ranging from 500 to 800 pounds per acre, are made to the ratoons. The amounts used will vary greatly with the appearance of the ratoons and the yield which is anticipated. The composition of the mixed fertilizer will vary appreciably, but a common formula calls for 7½ per cent of phosphates as P_2O_5, 11 to 12 per cent nitrogen, and 5 to 6 per cent of potash as K_2O. It will be seen that this heavier schedule of fertilization supplies from 112 to 187 pounds of P_2O_5 to the plant crop. This is accompanied by 180 to 300 pounds of nitrogen and 75 to 125 pounds of potash as K_2O.

This heavier fertilization is producing notably larger plants and heavier yields of fruit. Our results suggest, however, that the amount of nitrogen and phosphate, now applied, probably approaches the requirements of the crop for these two constituents. The amount of potash is still far below the extraction of this nutrient in plant and fruit. It should be remembered, however, that only the fruit is necessarily sold and received from the fields. The amount of potash removed in the fruit is comparatively small. It is in fact probably no more than is at present supplied in the mixed fertilizer. Our results suggest strongly that economy of fertilization and a desire for a permanent system of soil fertility should lead every grower to attempt to return the stumps and leaves of the ratoons to the soil after the growth of the plants is completed. Such a policy may require a special study of cultural practices, but the large quantity of plant nutrients contained in the stubble warrants effort and experimentation as to the best method of utilizing this valuable material. If such a course is not followed and the stubble and stumps are hauled away to be thrown in gulches or upon waste land, it is very clear that a notable potash shortage will eventually occur in many of the pineapple fields.

Summary

(1) The growth and composition of pineapple plants grown with and without mulching paper was determined at three-month intervals from the time of planting to thirty months of age.

(2) The plant crop grown under mulching paper was consistently larger than that grown on bare soil. The fruits produced were also larger in size. After fruiting the differences between the two sets of plants were less evident. Some growth failure later occurred in the ratoons so we shall base our deductions, largely, on the figures obtained on the plant crop.

(3) The composition of the pineapple plants grown on the paper and no paper plots was essentially the same at each period of sampling. Potash was the plant nutrient present in largest amount at all periods of growth. The percentage of potash was higher from the ninth to the fifteenth month than it was in the latter part of the sampling periods. Nitrogen was next to potash in the per cent present. It was found in largest amounts in the plants during the first fifteen to eighteen months of the plant's growth. Total sulphur was found present in largest amounts from the ninth to the fifteenth month. Phosphates were present in largest amounts from the sixth to the twenty-first month. Lime appeared to be present in essentially the same amounts at all periods.

(4) Potash was the largest plant nutrient present in the pineapple fruit. Next in order of magnitude was nitrogen, then lime and phosphate.

(5) The maximum absorption of plant nutrients by the pineapple crop was found to occur at the time of fruiting. Only a small portion of the nutrients taken up are present in the fruit.

(6) It is believed that the present systems of fertilization which supply increased amounts of nutrients, probably furnish sufficient quantities of the principal plant foods to supplement the natural fertility of the soil with the exception of potash. It is pointed out that only a small amount of the potash taken up by the plant is removed in the fruit. If the stubble is returned to the land when the ratoons are through fruiting, a heavy drain on soil potash may be avoided. If such a course is not followed, our results would indicate the probability of a future shortage of potash in pineapple soils.

Bibliography

(1) Methods of analyses of the Association of Official Agricultural Chemists, Revised to November 1, 1919.

(2) Burd, John S. Rate of absorption of soil constituents at successive stages of plant growth. Jour. Agr. Res., Vol. XVIII, 1919. No. 2, pp. 51-72.

(3) Jones, W. J., Jr., and Huston, H. A. Composition of maize at various stages of its growth. Ind. Agric. Exp. Sta. Bull. 175, 1914, pp. 599-630, 10 figures.

(4) Le Clerc, J. A., and Breazeale, J. F. Plant food removed from growing plants by rain or dew. U. S. D. A. Yearbook, 1908, pp. 389-402.

(5) Schweitzer, P. Study of the life history of corn at its different periods of growth. Missouri Agr. Exp. Sta. Bull. 9, pp. 1-78, 1889.

(6) Wilfarth, H., Römer, H., and Wimmer, G. Uber die Nahrstoffaufnahme der Pflanzen in Verschiedenen Zeiten Ihres Wachstums. Landw. Vers. Stat. Bd. 63, Hft. ½, pg. 1-70, plx. 3.

Sugar Prices

96° Centrifugals for the Period June 17, 1927, to September 15, 1927

Date		Per Pound	Per Ton	Remarks
June	17, 1927	4.55¢	$91.00	Cubas, 4.52, 4.58.
"	22	4.58	91.60	Porto Ricos.
"	29	4.52	90.40	Cubas.
July	8	4.58	91.60	Philippines.
"	11	4.61	92.20	Cubas.
"	12	4.58	91.60	Cubas.
"	13	4.535	90.70	Cubas, 4.55; Porto Ricos, 4.52.
"	19	4.52	90.40	Porto Ricos.
"	22	4.49	89.80	Philippines, 4.52; Cubas, 4.46.
"	26	4.46	89.20	Cubas.
"	28	4.505	90.10	Porto Ricos, 4.49; Cubas, 4.52.
Aug.	2	4.46	89.20	Cubas.
"	3	4.40	88.00	Porto Ricos.
"	5	4.46	89.20	Cubas.
"	8	4.445	88.90	Cubas, 4.46; Porto Ricos, 4.43.
"	10	4.46	89.20	St. Croix, 4.43; Porto Ricos, 4.49.
"	11	4.465	89.30	Philippines, 4.46; Cubas, 4.47.
"	12	4.46	89.20	St. Croix.
"	15	4.47	89.40	Cubas.
"	16	4.46	89.20	Cubas.
"	18	4.475	89.50	Philippines, 4.46, 4.49.
"	19	4.49	89.80	Philippines.
"	23	4.505	90.10	Philippines, 4.49; Cubas, 4.52.
"	24	4.58	91.60	Cubas.
"	25	4.6133	92.27	Philippines, 4.58; Cubas, 4.61, 4.65.
"	26	4.65	93.00	St. Croix.
"	31	4.71	94.20	Cubas.
Sept.	1	4.77	95.40	Porto Ricos.
"	7	4.80	96.00	Cubas, 4.77, 4.83; Philippines, 4.80.
"	8	4.83	96.60	Cubas.
"	9	4.77	95.40	Cubas.
"	15	4.87	97.40	Cubas.

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

OFFICERS FOR 1927

E. H. WODEHOUSE .... President
JOHN WATERHOUSE .... 1st Vice-President
R. A. COOKE .... 2nd Vice-President
R. D. MEAD .... Vice-President
J. K. BUTLER .... Secretary and Treasurer, and Director of Labor Bureau
H. A. WALKER .... Asst. Secretary and Asst. Director of Labor Bureau
S. O. HALLS .... Asst. Treasurer
F. C. ATHERTON .... Auditor

TRUSTEES FOR 1927

EXPERIMENT STATION COMMITTEE

J. E. RUSSELL, Chairman

C. R. HEMENWAY
T. H. PETRIE
J. W. WALDRON
HORACE JOHNSON
WILLIAM SEARBY

D. A. MEEK, Secretary

EXPERIMENT STATION STAFF

H. P. AGEE .... Director

R. C. L. PERKINS .... Consulting Entomologist
OTTO H. SWEZEY .... Entomologist
F. MUIR .... Entomologist
Associate Entomologist: C. E. PEMBERTON; Assistant Entomologists: F. X. WILLIAMS, R. H. VAN ZWALUWENBURG, G. H. CASSIDY (Assistant Nematologist), F. C. HADDEN.

H. L. LYON .... Botany and Forestry, in charge
Forest Supervisors: L. W. BRYAN (Hilo), GEORGE A. McELDOWNEY (Oahu), ALBERT DUVEL (Kauai). Assistant Botanist: E. L. CAUM. Supt. Vineyard St. Nursery: JOSEPH E. WIST. Assistant in Forestry: HUGH W. BRODIE.

W. R. McALLEP .... Sugar Technologist
Associate Sugar Technologist: W. L. McCLEERY. Technical Chemist: A. BRODIE. Assistant Chemists: H. A. COOK, H. F. BOMONTI, REGINALD H. KING.

GUY R. STEWART .... Chemist
Associate Chemists: W. T. McGEORGE, F. E. HANCE, FRED HANSSON. Assistant Chemists: C. L. CRUTCHFIELD, F. RAY VAN BROCKLIN, L. E. DAVIS, CARL W. NESBITT, ARTHUR AYRES, J. HOUSTON DUFFY.

J. A. VERRET .... Agriculturist
A. J. MANGELSDORF .... Geneticist
Assistant Agriculturists: Y. KUTSUNAI, F. C. DENISON, H. K. STENDER, R. E. DOTY, ALLISTER R. FORBES (Hawaii), A. J. WATT, JR. (Kohala), O. H. LYMAN (Maui), R. H. McLENNAN (Kauai); COLIN G. LENNOX (Assistant Geneticist). Assistant Agriculturists in Training: ROYDEN BRYAN, HERBERT DEVERILL, U. K. DAS, A. H. CORNELISON, V. EREMEEF, H. R. SHAW, G. W. FISHER.

H. ATHERTON LEE .... Pathologist
Assistant Pathologists: J. P. MARTIN, CLYDE C. BARNUM, C. W. CARPENTER. Histologist: D. M. WELLER.

W. TWIGG SMITH .... Illustrator
D. A. MEEK .... Chief Clerk
MABEL FRASER .... Librarian

TABLE OF CONTENTS

INDEX TO VOLUME XXXI

An asterisk preceding a page number indicates that the subject is illustrated.

A

B

C

D

E

F

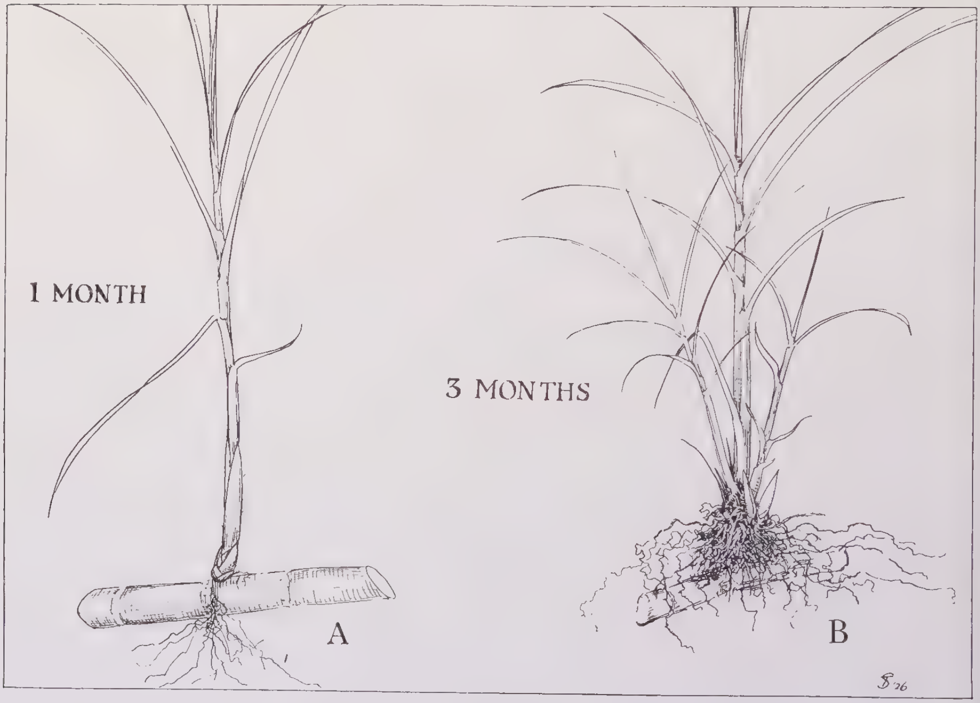
G

H

Page

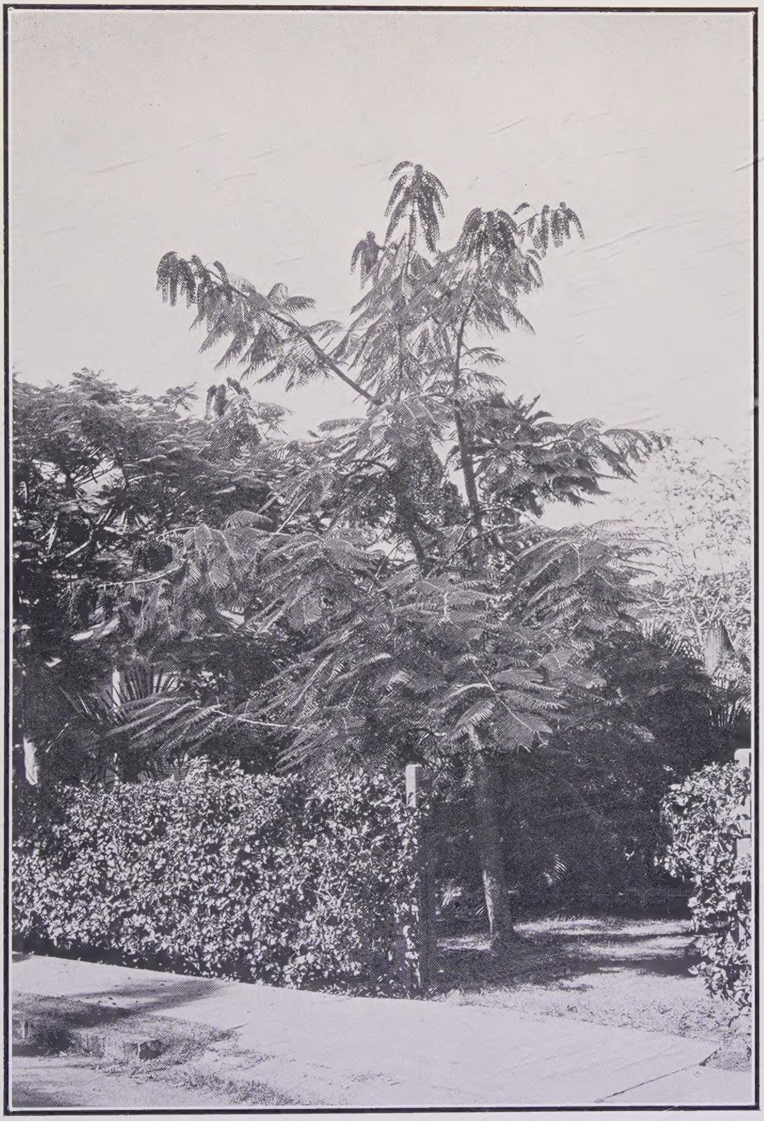
ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XXXI

JANUARY

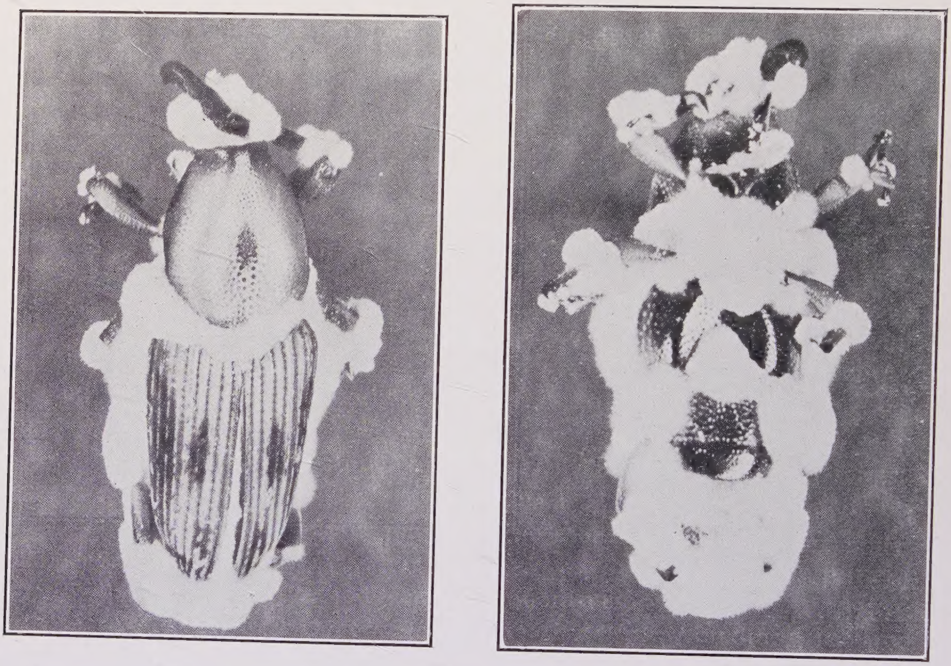


This sketch shows how plant cane is dependent upon the roots from the seed piece for the first month or more, the shoots thereafter developing their own root system. This explains in part the value of seed cane of prime quality in giving a field a quick start, as the plant food and water supplied by a poor rooting seed cane would be far less than in the case of a good one.

APRIL

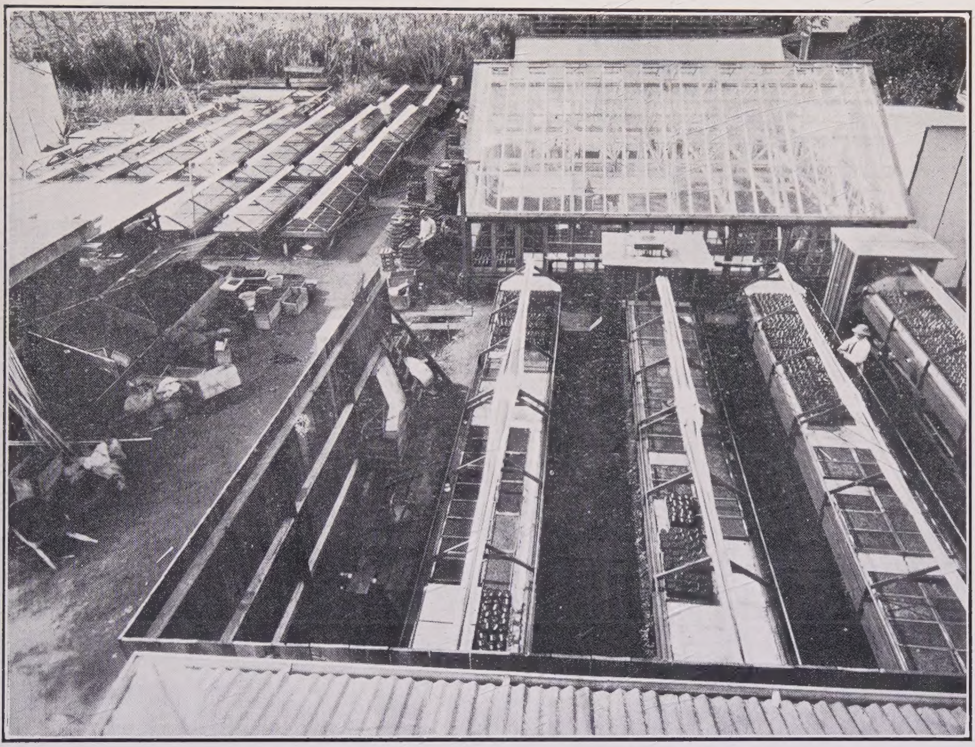


Colvillea racemosa. An ornamental tree new to Hawaii.



Fungus from Celebes attacking beetles closely related to our sugar cane beetle borer.

OCTOBER



Seedling equipment at the Experiment Station, showing in the foreground metal covered hot water heated benches, a new and helpful development.